UNITED STATES DEPARTMENT OF AGRICULTURE
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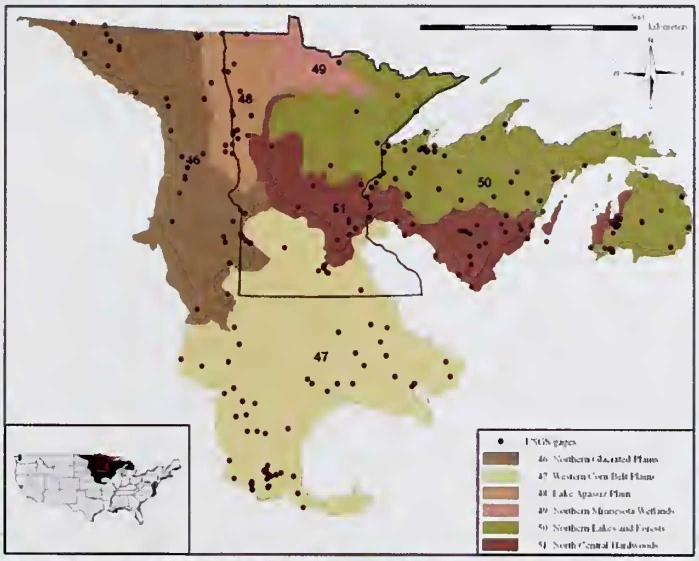
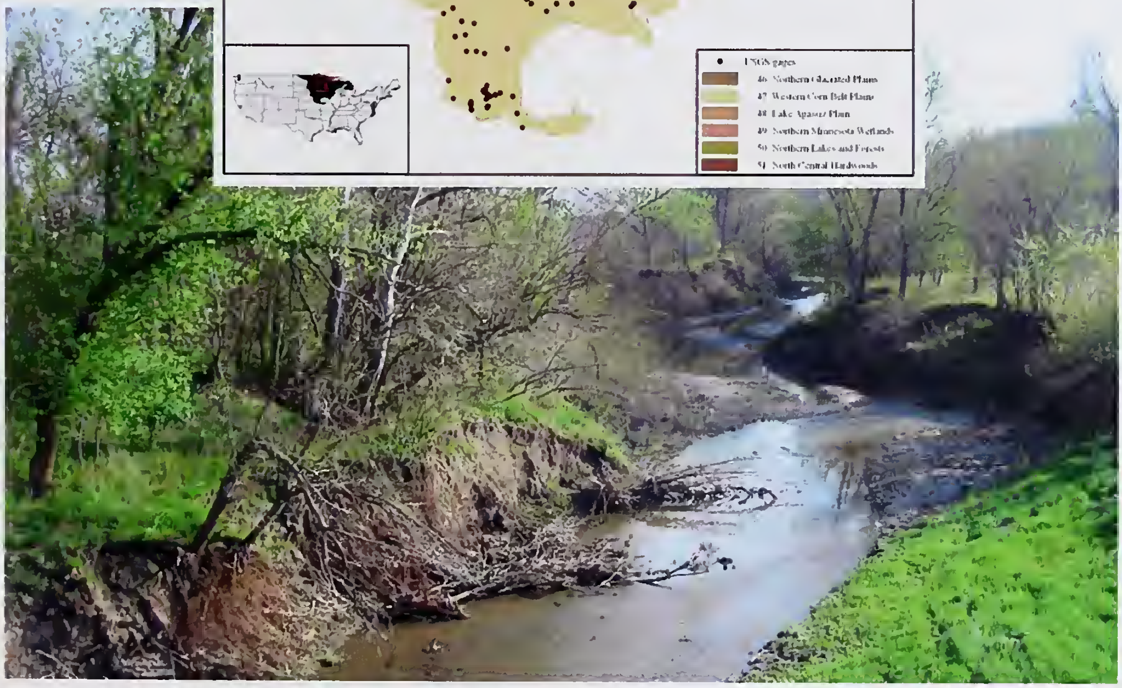
Characterization of "Reference" Suspended-Sediment Transport Rates for Level III Ecoregions of Minnesota





Lauren Klimetz and Andrew Simon

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Characterization of "Reference" Suspended-Sediment Transport Rates for Level III Ecoregions of Minnesota

Prepared by

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CHARACTERIZATION OF "REFERENCE" SUSPENDED-SEDIMENT TRANSPORT RATES FOR LEVEL III ECOREGIONS OF MINNESOTA

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EXECUTIVE SUMMARY

As a result of 'natural' and human-induced changes to precipitation, runoff production and land use water-quality issues due to excessive erosion and transport of suspended-sediment are a primary concern throughout the surface waters of Minnesota. Within Minnesota there are a number of Level III Ecoregions that are the subject of this investigation and report: Ecoregion 46, Northern Glaciated Plains; Ecoregion 47, Western Corn Belt Plains; Ecoregion 48, Lake Agassiz Plain; Ecoregion 50, Northern Lakes and Forest, and Ecoregion 51, Northern Central Hardwood Forests. Rapid Geomorphic Assessments carried out at current and historical USGS gaging stations found that more than half of sites visited in Ecoregions 46, 50 and 51 were considered stable, while the majority of sites in Ecoregion 47 and 48 were found to be unstable. Calculated suspended-sediment transport yields (load per unit area) at the 'effective discharge' (the flow that occurs, on average, once every 1.5 years or $Q_{1.5}$) and the mean annual yield were sorted into stable and unstable groups based on channel stability information. "Reference" suspended-sediment transport values were thus obtained from analysis of the distribution of suspended-sediment yields for streams determined to be geomorphically stable at the time of suspended-sediment sampling. At the $Q_{1.5}$ discharge, "reference" yields range over two orders of magnitude; from 0.0039 T/d/km^2 for Ecoregion 46, to 0.48 T/d/km^2 for Ecoregion 47. Mean-annual "reference" suspended-sediment yield values also varied by two orders of magnitude, from 0.351 T/y/km^2 to 20.3 T/y/km^2 also for Ecoregions 46 and 47, respectively. Statistical analysis of the differences between stable and unstable sites within each Level III Ecoregion were significant at the 0.05 probability level in all cases except Ecoregion 51 $Q_{1.5}$ yield values. However, stable and unstable values were statistically significant with the removal of two major outliers. This provides support for the overall approach of determining "reference" or 'target' rates for suspended-sediment transport and the development of TMDLs in Minnesota.

Where suitable data were available, other distinctions were made within each Level III Ecoregion. The majority of sites in all Ecoregions were dominated by a sand bed material (median diameter between 0.063 – 2 mm). There were, however, sufficient coarse-dominated stable channels (median particle diameter greater than 2 mm) within Ecoregions 47, 50 and 51 with which to calculate embeddedness for these Ecoregions. Embeddedness was calculated as the percentage of fine material present in a coarse dominated bed material. "Reference" values of embeddedness lie between an acceptable range of 5 and 10 %. Suspended-sediment yield data were also sorted by drainage-area size-classes and individual watershed in some cases, however insufficient data existed within each size-class to establish statistically significant trends, and the possibility of developing a "reference" transport rating equations for each Level III Ecoregion investigated.

All sediment-transport data were re-characterized in terms of the frequency and duration of suspended-sediment concentrations. Data in this format are potentially more useful to biologists and aquatic ecologists seeking functional links between sediment transport and biological metrics. In addition sediment 'dosage' was calculated as the product of concentration and duration and was also differentiated by stability class. 'Dosage

impact' then represents the difference in sediment dosage for stable and unstable conditions at a given concentration exceedance. Median suspended-sediment concentrations (in milligrams per liter) are lower in stable or "reference" channels at a given percent exceedance (or frequency) than in unstable channels in Ecoregions 46 and 50. Therefore, unstable channels consistently transport higher concentrations of suspended-sediment than stable channels in the both the Northern Glaciated Plains and the Northern Lakes and Forests. In Ecoregions 47, 48 and 51 this is true during moderate and high flows, those exceeded only 20 % of the time. This same pattern is evident when considering the frequency-magnitude and duration of concentration events between stable and unstable channels within each ecoregion. Sediment-dosage data show distinct differences between stable and unstable sites across the range of concentrations for the most part in all Ecoregions in Minnesota. Ecoregion 47 has the highest dosage values, in terms of both stable and unstable channels, while Ecoregion 50 has the lowest, and the clearest separation between stable and unstable channels. "Reference" suspended-sediment dosage peaks during frequently exceeded concentrations; those greater than 99 % of the time, therefore low concentration events. The only exception to this is Ecoregion 46, where data are skewed by ephemeral streams. This implies that low frequency, high concentration events may have a greater affect on sediment-sensitive organisms.

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1. INTRODUCTION AND PROBLEM

Excessive erosion and transport of sediment in the nation's surface waters has resulted in sediment being listed as the principle pollutant of surface waters in the United States by the 1996, 1998, and 2002 National Water Quality Inventory (Section 305 (b) Report to Congress). Water-quality impairment by sediment can be separated into two groups: sediment quality, where impairment is due to chemical constituents adsorbed onto the surface of fine-grained sediments, and sediment quantity where impairment is due to the amount of sediment in transport and/or alteration of substrate materials (bed material) by erosion or deposition.

EPA water quality information from across the nation found siltation to be the leading cause of water quality impairment in 1996, 1998 and 2002. In 2000 siltation ranked a close second to pathogens, while it ranked third in 2004, to pathogens and mercury. This information has been compiled from the various Water Quality Reports available online in Tables 1 and 2. However, EPA does state that such data should not be used to compare water quality conditions between states or identify national trends due to differences in state assessment methods and changes in EPA guidance. Comparison of data between states should be made with caution, as the various states participating in data collection are not required to use a unified methodology.

For the purpose of developing water-quality target values for sediment, sediment-transport rates and amounts can be viewed as (1) "natural," "reference" or background, resulting from generally stable channel systems, (2) "impacted", with greater transport rates and amounts, reflecting a disturbance of some magnitude and more pervasive erosion, and (3) "impaired", where erosion and sediment-transport rates and amounts are so great that biological communities and other designated stream uses are adversely affected. Impairment of designated stream uses by clean sediment (neglecting adsorbed constituents) may occur along channel bed such as deposition of fines amidst a coarser-grained substrate, or by elevated concentrations of suspended-sediment in the water column. Fully mobile streambeds and deposition of fines amidst interstitial streambed gravels, can pose hazards to fish and benthic macro-invertebrate communities by disrupting habitats, degrading spawning habitat, and reducing the flow of oxygen through gravel beds. Although lethal or sub-lethal thresholds are currently unknown for many species, high concentrations of suspended-sediment over certain durations have been shown by Newcombe *et al.* (1991, 1996) to adversely affect aquatic organisms. It is therefore important to determine the quantity and quality of sediment within a river system that does not adversely impact the specified designated uses.

One way of accomplishing this is by differentiating between rates and conditions of sediment transport for stable and unstable streams within a given area or region. Unimpaired or stable, "reference" streams are defined in geomorphic terms for the purpose of this report. A stable stream is one in dynamic equilibrium, capable of transporting all sediment delivered to the system from upstream, without altering its dimensions over a period of years. Conversely, an unstable stream is one in which the supply of sediment from upstream is not in balance with the ability of the stream to transport that sediment through the reach without alterations to its geometry over a period of years.

Using this general concept, "reference" suspended-sediment transport rates have been developed for various Level III ecoregions of the United States (Simon *et al*., 2004a), for ecoregions in EPA Region 4 (Southeastern United States) by Klimetz and Simon (2006) and Simon and Klimetz, *in press*) and a select number of ecoregions in EPA Region 8 (Simon *et al.,* 2008). The continental United States is divided into 84 Level III ecoregions, which have similar characteristics, including among others, climatic and physiographic conditions, geology and ecology (Omernik, 1995). Minnesota includes parts of seven Level III Ecoregions: Northern Glaciated Plains (#46), Western Corn Belt Plains (#47), Lake Agassiz Plain (#48), Northern Minnesota Wetlands (#49), Northern Lakes and Forest (#50), Northern Central Hardwood Forest (#51) and The Driftless Area (#52). These Ecoregions lie mainly in Iowa, Michigan, Minnesota, North Dakota, South Dakota and Wisconsin but also include parts of Kansas, Missouri and Nebraska. Suspended-sediment transport rates are not calculated for Ecoregions 49 and 52 as part of this study due to insufficient data availability.

This study aimed to determine suspended-sediment transport rates for "reference" (stable) streams, specific to the Level III ecoregions of Minnesota, with the intention that the methodology and findings will be used by States and Tribes, as well as the Environmental Protection Agency (EPA) to further develop sediment TMDLs in Minnesota (Figure 1).

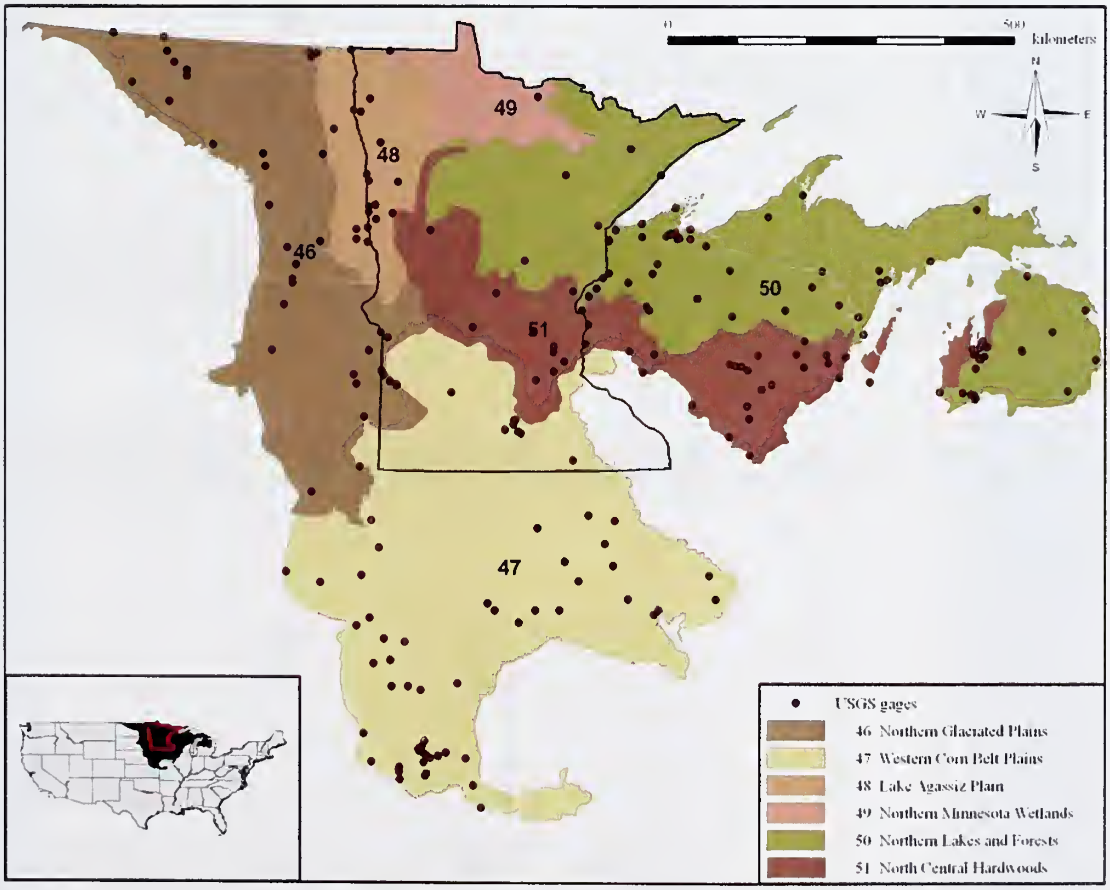


Figure 1 – Location map showing EPA Level III Ecoregions within Minnesota and USGS gages with sufficient suspended-sediment samples; 46, 47, 48, 49, 50 and 51.

Table 1 – Compilation of data from the National Water Quality Inventory Report to Congress (305(b) Report) for the states relevant to Ecoregions located within Minnesota.

State	Total miles of river and streams	Year of report	Total river miles assessed for water quality		Overall Water Quality Attainment for Rivers and Streams (river miles) Good		Threatened		Impaired	
Iowa	71665	2004	7830.16	10.93%	1867.56	23.85%	2627	33.55%	3335.71	42.60%
		2002	6871.19	9.59%	1938.18	28.21%	2318	33.74%	2614.86	38.06%
		2000	6390	9.00%	1702.60	26.64%	2784	43.60%	1903.10	29.78%
Kansas	134338	2006	18492.94	13.77%	9892.24	53.49%	1299	7.02%	7301.94	39.49%
		2004	19494.61	14.51%	8692.95	44.59%	-	-	10801.66	55.41%
		2002	19827.42	14.76%	4821.73	24.32%	-	-	15005.69	75.68%
		2000	18236	14.00%	3417	18.74%	-	-	14819	81.26%
		1996	19330			91.00%				9.00%
Michigan	49136	2002	22075.09	44.93%	19073.97	86.40%	-	-	3001.12	13.60%
	51438	2000	10309	26.00%	7829	75.94%	24	0.23%	2456	23.82%
		1996								
Minnesota	91944	2006	11466.49	12.47%	2255.96	19.67%	-	-	9210.53	80.33%
		2004	9878.79	10.74%	19094.24	37.75%	-	-	31490.01	62.25%
		2002	5048.91	5.88%	2402.8	44.42%	527.06	9.74%	2479.05	45.83%
		2000	11403	12.00%	1149.6	10.24%	2181.7	19.43%	7899.6	70.33%
		1996	7793			10.00%		39.00%		51.00%
Missouri	51978	2006	22054.2	42.43%	10330.9	46.84%	-	-	11723.3	53.16%
		2004	22046.7	42.42%	10437.2	47.34%	-	-	11609.5	52.66%
		2002	22194.2	42.70%	-	-	3571.5	16.09%	18622.7	83.91%
		2000	21615.1	42.00%	11129	51.49%	164.2	0.76%	10321	47.70%
Nebraska	81573	2004	7155.83	8.77%	3872.05	54.11%	0	0.00%	3283.78	45.89%
		2002	7580.67	9.29%	3136.13	41.37%	101.4	1.34%	4343.14	57.29%
		2000	6500	8.00%	2741	42.17%	0	0.00%	3759	57.83%
		1996	81573			25.00%		9.00%		67.00%

State	Total miles of river and streams	Year of report	Total river miles assessed for water quality		Overall Water Quality Attainment for Rivers and Streams (river miles)					
					Good		Threatened		Impaired	
North Dakota	54427	2006	8640.91	15.88%	2600.69	30.10%	3342.88	38.69%	2697.34	31.22%
		2004	9176.83	16.86%	2990.99	32.59%	3835.47	41.80%	2350.37	25.61%
		2002	7708.88	14.16%	2302.32	29.87%	3298.87	42.77%	2109.69	27.37%
		2000	14965	27.00%	1656.9	11.07%	6083.5	40.65%	7224.2	48.28%
		1996	53989			9.00%		62.00%		29.00%
South Dakota	9937	2006	7537.29	75.85%	3737.88	49.59%	10.6	0.14%	3788.81	50.27%
		2004	7375.63	74.22%	4233.33	57.40%	10.6	0.14%	3131.7	42.46%
		2002	4265.2	42.92%	1823.6	42.76%	-	-	2441.6	57.24%
		2000	3564	36.00%	1786	50.11%	-	-	1778	49.89%
		1996	9937			17.00%		0.00%		83.00%
Wisconsin	55000	2006	15131.99	27.51%	5928.93	39.18%	3.97	3.00%	9199.09	60.79%
		2004	14139.2	25.71%	6112.71	43.23%	34.84	0.25%	7991.65	56.52%
		2002	25209.66	45.84%	7934.51	31.47%	5014.2	19.89%	12260.95	48.64%
		2000	23530	43.00%	6858	29.15%	6634	28.19%	10029	42.62%
		1996	19149			33.00%		23.00%		44.00%
Nationwide	3692830	2002	695540.37	18.83%	358034.88	51.48%	27749.97	3.99%	309755.53	44.53%
		2000	699946	19.00%	367129	53.00%	59504	8.00%	269258	39.00%
		1998	842426	23.00%	463441	55.00%	85544	10.00%	291264	35.00%
		1996	693905	19.00%		56.00%		8.00%		36.00%

Compiled from:

EPA (2004a). National Assessment Database available online at: http://www.epa.gov/waters/305b/index.html

EPA (2002a). Water Quality Report to Congress

EPA (2000). Water Quality Report

EPA (1998). Water Quality Report to Congress

EPA (1996). Water Quality Report to Congress

Table 2 – Major causes of pollution in rivers and streams across the United States, in order of severity.

	Cause of Pollution			
	2002	**2000**	**1998**	**1996**
1	**Sedimentation/siltation**	Pathogens	**Sedimentation/siltation**	**Sedimentation/siltation**
2	Pathogens	**Sedimentation/siltation**	Pathogens	Nutrients
3	Habitat alterations	Habitat alterations	Nutrients	Bacteria
4	Metals	Oxygen-depleting substances	Oxygen-depleting substances	Oxygen-depleting substances
5	Nutrients	Nutrients	Metals	Pesticides
6	Thermal modifications	Thermal modifications	Pesticides	Habitat alterations
7	Organic enrichment/low Dissolved Oxygen	Metals	Habitat alterations	Suspended solids
8	Flow alterations	Flow alterations	Thermal modifications	Metals
9	Cause unknown			
10	pH/acidity/caustic conditions			

2. OBJECTIVES

The main purpose of this study was to use scientifically-defensible methodologies by which to determine "reference" suspended-sediment transport rates for Level III Ecoregions located in Minnesota. Suspended-sediment transport yields, expressed as mass per unit drainage area ($T/d/km^2$) were to be initially calculated at a constant flow-recurrence interval representing the channel-forming or effective discharge ($Q_{1.5}$; Simon *et al.* (2004a), derived from the annual maximum discharge series. Results provided in this format to other States and EPA regions indicated that a transport rate representing annual values would be easier for stakeholders to grasp. As transport rates at the effective discharge ($Q_{1.5}$) cannot be multiplied by 365 to obtain an annual suspended-sediment transport value, an additional goal was to determine "reference" annual transport rates using mean-daily discharge data for all sites.

As suspended-sediment transport rates expressed as yields (as in $T/y/km^2$) cannot be functionally related to the life cycle of aquatic biota, a secondary objective of this study was to create additional sediment-transport metrics that could ultimately be used by biologists and aquatic ecologists to develop functional links between sediment and biota.. These metrics follow the concepts expressed in Newcome, *et al.* (1991) that consider the frequency and duration of concentrations of various magnitudes (Klimetz and Simon, 2006; Simon and Klimetz, in press).

The geographic scope of this project encompasses the Level III Ecoregions located within Minnesota (Table 3): Northern Glaciated Plains (#46), Western Corn Belt Plains (#47), Lake Agassiz Plain (#48), Northern Lakes and Forest (#50), and the Northern Central Hardwood Forest (#51), which also includes parts of Iowa, Kansas, Michigan, Missouri, Nebraska, North Dakota, South Dakota and Wisconsin.

Table 3 – Primary distinguishing characteristics of the Level III Ecoregions located within Minnesota.

	Ecoregion	States	Number of gages[1]	Primary distinguishing characteristics[2]
46	**Northern Glaciated Plains**	**Minnesota, North Dakota, South Dakota**	38	The Northern Glaciated Plains ecoregion is characterized by a flat to gently rolling landscape composed of glacial till. The subhumid conditions foster a transitional grassland containing tallgrass and shortgrass prairie. High concentrations of temporary and seasonal wetlands create favorable conditions for waterfowl nesting and migration. Though the till soils are very fertile, agricultural success is subject to annual climatic fluctuations
47	**Western Corn Belt Plains**	**Iowa, Kansas, Minnesota, Nebraska**	63	Once covered with tallgrass prairie, over 75 percent of the Western Corn Belt Plains is now used for cropland agriculture and much of the remainder is in forage for livestock. A combination of nearly level to gently rolling glaciated till plains and hilly loess plains, an average annual precipitation of 63-89 cm, which occurs mainly in the growing season, and fertile, warm, moist soils make this on of the most productive areas of corn and soybeans in the world. Major environmental concerns in the region include surface and groundwater contamination from fertilizer and pesticide applications as well as impacts from concentrated livestock production.
48	**Lake Agassiz Plain**	**Minnesota, North Dakota**	13[3]	Glacial Lake Agassiz was the last in a series of proglacial lakes to fill the Red River valley in the three million years since the beginning of the Pleistocene. Thick beds of lake sediments on top of glacial till create the extremely flat floor of the Lake Agassiz Plain. The historic tallgrass prairie has been replaced by intensive row crop agriculture. The preferred crops in the northern half of the region are potatoes, beans, sugar beets and wheat; soybeans, sugar beets, and corn predominate in the south.
50	**Northern Lakes and Forests**	**Michigan, Minnesota, Wisconsin**	60	The Northern Lakes and Forests is a region of nutrient poor glacial soils, coniferous and northern hardwood forests, undulating till plains, morainal hills, broad lacustrine basins, and extensive sandy outwash plains. Soils in this ecoregion are thicker than in those to the north and generally lack the arability of soils in adjacent ecoregions to the south. The numerous lakes that dot the landscape are clearer and less productive than those in ecoregions to the south.
51	**North Central Hardwood Forest**	**Minnesota, Wisconsin**	49	The North Central Hardwood Forests is transitional between the predominantly forested Northern Lakes and Forests to the north and the agricultural ecoregions to the south. Land use/land cover in this ecoregion consists of a mosaic forests, wetlands and lakes, cropland agriculture, pasture, and dairy operations.

[1] Number of USGS gage with 15 or more suspended-sediment samples and associated discharge.

[2] Source: EPA (2002b) available online at: http://www.epa.gov/wed/pages/ecoregions/level_iii.htm

[3] Due to an insufficient number of gages with at least 15 suspended-sediment samples and associated instantaneous discharge, four sites were added for which discharge was calculated from mean daily discharge values

3. BACKGROUND AND DATA AVAILABILITY

EPA compiled water-quality data from approximately one million river kilometers of channels (about 19 % of the nation's waterways) that had been assessed by States, Territories and Tribes across the Nation in 2002. More than 160,000 river kilometers were significantly impaired as a result of sedimentation/siltation (2002 National Water Quality Inventory Report to Congress (305(b)). Sediment was, therefore, found to be the number one factor contributing to pollution of the nation's surface waters in 2002. Those same States, Territories and Tribes are then required to determine the maximum allowable loadings to, or in a stream that does not impair the "designated use" of that particular water-body. This measure has been termed a TMDL (total maximum daily load). From a technical point of view, however, this should not mean that a TMDL for sediment transport needs to be expressed in terms of a total load, or a daily-maximum load. In fact neither of these metrics may be appropriate for sediment. Other metrics used to describe "reference", impacted and impaired sediment-transport conditions such as suspended-sediment yields and concentration frequency-duration are probably more meaningful.

Initial considerations regarding the flow discharge to be used to calculate sediment loads or yields focused on a geomorphically effective flow. Historically, the bankfull discharge has been used because it has been assumed to represent a channel-forming discharge (Leopold and Maddock, 1953). In fact, renewed interests in rehabilitation and restoration of stream channels has resulted in renewed popularity of using this flow for channel design (Rosgen, 1996). Because the bankfull flow has been ascribed by some over the years as having geomorphic significance as the channel-forming flow representing long-term sediment-transport conditions it deserves further attention here as a potential metric for sediment-transport conditions. However, in lieu of form-based estimates of the bankfull level, a flow of a given frequency and recurrence interval is perhaps more appropriate to integrate suspended-sediment transport rates for the purpose of defining long-term transport conditions at sites from diverse regions.

3.1 Bankfull Discharge, Effective Discharge and the $Q_{1.5}$

The bankfull discharge has been ascribed various meanings and levels of importance over the past 50 years since Leopold and Maddock (1953) published their research on hydraulic geometry. This work established an empirical framework for observed differences in the size and shape of alluvial channels as a function of bankfull discharge. Based on the annual-maximum flow series, the recurrence interval of the bankfull discharge often approximates the 1.5-year flow event (Dury et al., 1963; Leopold et al., 1964; Hickin, 1968; Dunne and Leopold, 1978; Williams, 1978; Harman et al., 1999; Odem et al., 1999; Castro and Jackson, 2001) although substantial variations around this average value have been noted (Williams, 1978).

Sediment water-quality issues have been linked to conditions at bankfull discharge as a potential means of identifying impacted stream systems based on "departure" from "background" or "reference" sediment-transport conditions (Simon et al., 2001). The

bankfull discharge is the maximum discharge that can be contained within the channel without overtopping the banks (Leopold et al., 1964) and generally accepted to represent the flow that occurs, on average, every 1.5 years ($Q_{1.5}$). Dunne and Leopold (1978) described the discharge at the bankfull stage as the most effective at forming and maintaining average channel dimensions. This has led to the term "bankfull discharge" being often used interchangeably with the terms effective discharge, channel-forming discharge, and dominant discharge. The simple definition of bankfull by Leopold et al. (1964), as the "flow that just spills out onto the floodplain" has been used and abused over the years (Williams, 1978). One of the primary reasons for this confusion is that as originally defined bankfull discharge and the dimensions represented by hydraulic geometry relations refer to stable channels. A bankfull level in unstable streams can be exceedingly difficult to identify particularly in erosional channels because of a lack of depositional features and because channel dimensions, including water-surface elevations (of specific discharges), are changing with time. In searching for a meaningful discharge or range of discharges to compare sediment-transport rates and by alleviating the need for the form-based bankfull criteria is to use a consistent flow-frequency value that can be linked to geomorphic processes, alluvial channel form, and hence, sediment-transport rates.

The *effective discharge* is the discharge or range of discharges that transports the largest proportion of the annual suspended-sediment load over the long term (Wolman and Miller, 1960). In subsequent years various authors (Andrews, 1980; Andrews and Nankervis 1995; Whiting et al, 1999; Emmett and Wolman, 2001; and others) have altered the original definition of effective discharge from suspended-sediment load to include bed load, bed-material load, or total load to accommodate their particular sampling or analytic program. This is justified on the basis that "bed-load…is the most relevant from the standpoint of channel form adjustment…" (Knighton, 1998, p. 164). This, however, is a surprising assertion, as in most cases the suspended load represents the bulk of the annual sediment load. These authors have found that the effective discharge for bed load may be represented by the $Q_{1.5}$ (discharge with a recurrence interval of, on average, 1.5 years). In stable, non-incised stream systems, the $Q_{1.5}$ may be represented by the bankfull stage (Dunne and Leopold, 1978). For the purposes of this report we will use the definition of effective discharge as originally defined by Wolman and Miller (1960) to represent suspended-sediment transport.

The ratio between effective and bankfull discharges does however, tend to diverge from unity with the magnitude of large, infrequent events (Wolman and Miller, 1960; Pickup and Warner, 1976; Nolan et al., 1987; Whiting, et al., 1999). Pickup and Warner (1976) found the return period of the effective discharge to range between 1.15 and 1.4 years (from the annual maximum series) using bed load transport equations to estimate sediment transport. With data from 55 streams, Nash (1994) questioned the validity of the effective discharge occurring on about 1-year intervals based on concerns of transport variability and the difficulty of describing the relation between suspended-sediment concentration and water discharge with a power function. However using a vast dataset of approximately 500 sites within the United States, Simon *et al.* (2004a) calculated the recurrence interval of the effective discharge for suspended-sediment transport. The median recurrence interval ranged from 1.1 to 1.7 years, across 17 different ecoregions

with varying hydrologic and topographic conditions. The conclusions of this report were that "the $Q_{1.5}$ proved to be a reasonably good measure of the effective discharge for suspended-sediment", and can therefore be used across a range of spatial scales in diverse environments to compare suspended-sediment transport rates.

3.2 Availability of Data

Analysis of suspended-sediment transport at the national scale requires a large database of suspended-sediment concentrations with associated instantaneous water discharge. Data of this type permit analysis of sediment-transport characteristics and the development of rating relations (Porterfield, 1972; Glysson, 1987). Collection of suspended-sediment data is time consuming and expensive in that it must take place over a broad range of flows to accurately evaluate the long-term, sediment-transport regime at a site. However, the U.S. Geological Survey (USGS) has identified more than 6000 sites nationwide where at least 1 matching sample of suspended sediment and instantaneous flow discharge have been collected (Turcios and Gray, 2001). Over 200 USGS gages have at least 15 suspended-sediment samples with associated instantaneous discharge data (Table 3, above), ranging from 13 in Ecoregion 48, Lake Agassiz Plain, to Ecoreigon 47, the Western Cornbelt Plains, with 63 sites with sufficient data to create a transport rating relation. At many of these sites, data on the particle-size distribution of suspended- and bed-material sediment are also available. USGS and ARS suspended-sediment sampling strategies are usually designed to obtain samples over a broad range of flows, particularly during storms when a large proportion of the annual load may be transported. In addition, peak-flow files maintained by the USGS were available for most of the sites. This massive historical database serves as the foundation for analyzing sediment-transport characteristics over the entire range of phyisiographic conditions that exist in the United States. Finally, it should be stressed that the sediment-transport rates reported here represent two phases of sediment movement; wash load (generally silts and clays) and suspended bed-material load (generally sands), but excludes bed load. Stream systems dominated by bed load, therefore, may not be well represented here.

To be useful for TMDL practitioners, sediment-transport relations must be placed within a conceptual and analytical framework, such that they can be used to address sediment-related problems at sites where no such data exists. To accomplish this, sediment-transport characteristics and relations need to be regionalized according to attributes of channels and drainage basins that are directly related to sediment production and transport. In a general way, attributes such as physiography, climate, geology, and ecology are differentiated within the ecoregion concept (Omernik, 1995). Ecoregions are convenient units with which to regionalize investigations concerning dominant channel processes, differentiated as stage of channel evolution (Simon and Hupp, 1986; Simon, 1989a). These Ecoregion divisions have been used successfully as a means of regionalizing hydraulic-geometry relations in the Pacific Northwest (Castro and Jackson, 2001) and for developing 'reference sediment-transport conditions in a range of ecoregions across the United States (Simon *et a.l.* 2004a and 2008, Klimetz and Simon, 2006; Simon and Klimetz, in press).

4. METHODOLOGY

Two main data sources were used during the course of this study:

1. **Existing Precipitation, Flow and Sediment Data**
Information and data regarding suspended-sediment and flow were obtained from U.S. Geological Survey (USGS) Web sites (http://water.usgs.gov) while precipitation data were obtained from National Oceanic and Atmospheric Administration (NOAA) Web sites (http://www.ncdc.noaa.gov/oa/climate/research/ushcn/ushcn.html). The data were initially sorted by Level III Ecoregion and placed in various matrices to examine spatial and temporal trends in the data, as well as to calculate "reference" suspended-sediment yields other metrics.

2. **Current and Historical Channel-Stability Conditions**
Current channel-stability conditions were determined through field data collection at sites with existing flow and sediment data. Rapid Geomorphic Assessments (RGAs) were carried out to determine relative channel stability at USGS gaging-station locations with sufficient historical suspended-sediment and associated instantaneous-discharge data. Bed material was sampled at each location to determine relative embeddedness. For those sites where current stability conditions could not be related to historical sediment sampling, discharge-measurement data from the USGS were analyzed to determine trends of channel depth and width over time.

4.1 Existing Precipitation, Flow and Sediment Data

There was a wide range of historical and current data available from various sources concerning flow and precipitation in Minnesota. The majority of the flow and sediment data were downloaded from USGS Web sites. These data include:

1. suspended-sediment concentration, and associated instantaneous flow discharge,
2. annual peak discharge,
3. mean-daily flows,
4. summaries of instantaneous stream-flow measurements (USGS, 9-207 forms),
5. bed-material composition, and
6. precipitation.

(1) Suspended-sediment concentration and associated flow discharge at time of sampling were downloaded from USGS websites (http://nwis.waterdata.usgs.gov/usa/nwis/qwdata) and used to develop relations between sediment transport and discharge over the range of flows at each site. These relations serve as the fundamental analytic unit for calculations of sediment-transport rates as concentrations (in milligrams per liter, mg/l), loads (in metric tonnes, T) and yields in metric tonnes per day (or year) per square kilometer.

(2) Annual peak discharges for the period of record at each station (Appendix A) were downloaded from USGS websites (http://nwis.waterdata.usgs.gov/usa/nwis/peak) and used to develop the frequency distribution of peak flows for each site. These data were

then used to calculate the discharge of the 1.5 recurrence-interval flow and subsequently, to obtain the suspended-sediment load at in T/d at the $Q_{1.5}$. Dividing by basin area produced a suspended-sediment yield for the $Q_{1.5}$ in T/d/km^2.

(3) Mean-daily flows were downloaded for the period of record for each site from USGS websites (http://nwis.waterdata.usgs.gov/nwis/dv; Appendix A). Data for each day of record were used to determine the suspended-sediment load for that day (based on the sediment-transport relation) and summed for each year to obtain annual loadings values for each site. If a site had missing days of discharge data, loads were not calculated for those days and that year was not included in average annual calculations. An average annual suspended-sediment load (in metric T/y) was obtained by summing all of the annual loads at a site and dividing by the number of years of complete record. An annual suspended sediment yield in T/y/km^2 was obtained by dividing by basin area.

(4) Summaries of instantaneous streamflow measurements made by the USGS for each site were used to determine relative stability conditions during periods of historical sampling. These summaries provide information on water-surface width, flow depth and gage height and other parameters for each discharge measurement. On average, between six and 10 measurements are made per year. Relations were established between flow depth and stage, and flow width and stage for decadal or shorter time periods to determine if these relations were changing with time. A shift in these relations provide evidence of historical instability and were used to sort sites into stable and unstable groups where current geomorphic assessments had no bearing on geomorphic conditions during the period of sediment sampling.

(5) Where available, data on bed-material composition were downloaded from USGS Web sites and used for two purposes. First, these data as well as bed-material samples collected in the field were used to differentiate between "reference" conditions within specific ecoregions for streams dominated by different size classes (ie. silt/clay, sand, and gravel/cobble). Second, the data were used to calculate a measure of embeddedness for gravel-dominated streams (percent finer than 2mm) to investigate differences between stable and unstable streams in a specific ecoregion.

(6) Daily precipitation data were downloaded from NOAA Web sites (http://www.ncdc.noaa.gov/oa/climate/research/ushcn/ushcn.html) to evaluate trends over the past 100 years. Although these data were not used directly in calculations of suspended-sediment transport rates, in combination with water yield data (expressed as flow discharge per unit drainage area; m^3/km^2) they allowed for interpretations of changing flow regimes and land-use effects over the past century.

The methods used in this study follow a tested procedure aimed at developing defensible estimates of current sediment loads relative to "reference" suspended-sediment transport rates. A "reference" suspended-sediment transport rate is representative of stable streams within a specific ecoregion and can be defined as a concentration (in milligrams per liter; mg/l), a load (in metric tonnes per day or year; T/d or T/y) or a yield (in tonnes per day per square kilometer, T/d/km^2; or tonnes per year per square kilometer, T/y/km^2). Yield is a preferred parameter as it is independent of stream size, allowing the comparison of streams of different basin areas.

4.1.1 Suspended-Sediment Transport Rating Relations

Analysis of suspended-sediment transport data at each USGS gaging station involves establishing a relation between flow and sediment concentration, or load. Instantaneous-concentration data combined with either an instantaneous flow value or flow data representing the value obtained from the stage-discharge relation at 15-minute intervals are best. Mean-daily values of both flow and sediment loads, which are readily available from the USGS, tend to be biased towards lower flows, particularly in flashy basins. To establish sediment-transport rating relations, instantaneous concentration and 15-minute flow data were used from USGS gaging-station records (Appendix B, all rating relations given by this table pertain to one original regression). Simon (1989) showed how the slope of sediment-transport relations varies over time and the course of fluvial adjustment. Kuhnle and Simon (2000) indicated that the coefficient of the rating relation may also be useful as a generalized measure of sediment-transport rates, particularly at low flows. It seems, however, that the suspended-sediment transport rate at the "effective discharge" may hold the greatest potential as a measure of sediment transport when comparing a large number of sites in a specific region. Although the effective discharge represents only one point along the transport relation, it can be viewed as an integration of the entire relation if we accept the time-based concepts implicit in its definition.

Suspended-sediment transport relations are empirical representations of the sediment-transport regime at a given gaging station location, reflecting geomorphic, hydraulic and other watershed processes operating upstream. It is acknowledged that these power functions tend to mask specifics of governing sediment-transport processes, yet they still provide a useful foundation for calculating the amount of suspended sediment being transported over a broad range of flows (four or five orders of magnitude in many cases; Figure 2). Because the relations between water discharge and suspended-sediment load or concentration are approximate, typically high coefficients of determination between these variables (for example 0.90) may still have order-of-magnitude 95% prediction limits. This is generally caused by the natural variability of sediment-transport processes, rather than errors in suspended-sediment measurements. Predictions of the rate of sediment transport at a particular place and time are, therefore, not exact. However, prediction of mean transport rates over a suitably long period of time (represented by a transport relation) should have a higher degree of reliability if a dataset has been collected over the range of flows. Therefore, this is a valid means of describing and comparing the suspended-sediment transport regimes for streams from a broad range of environments.

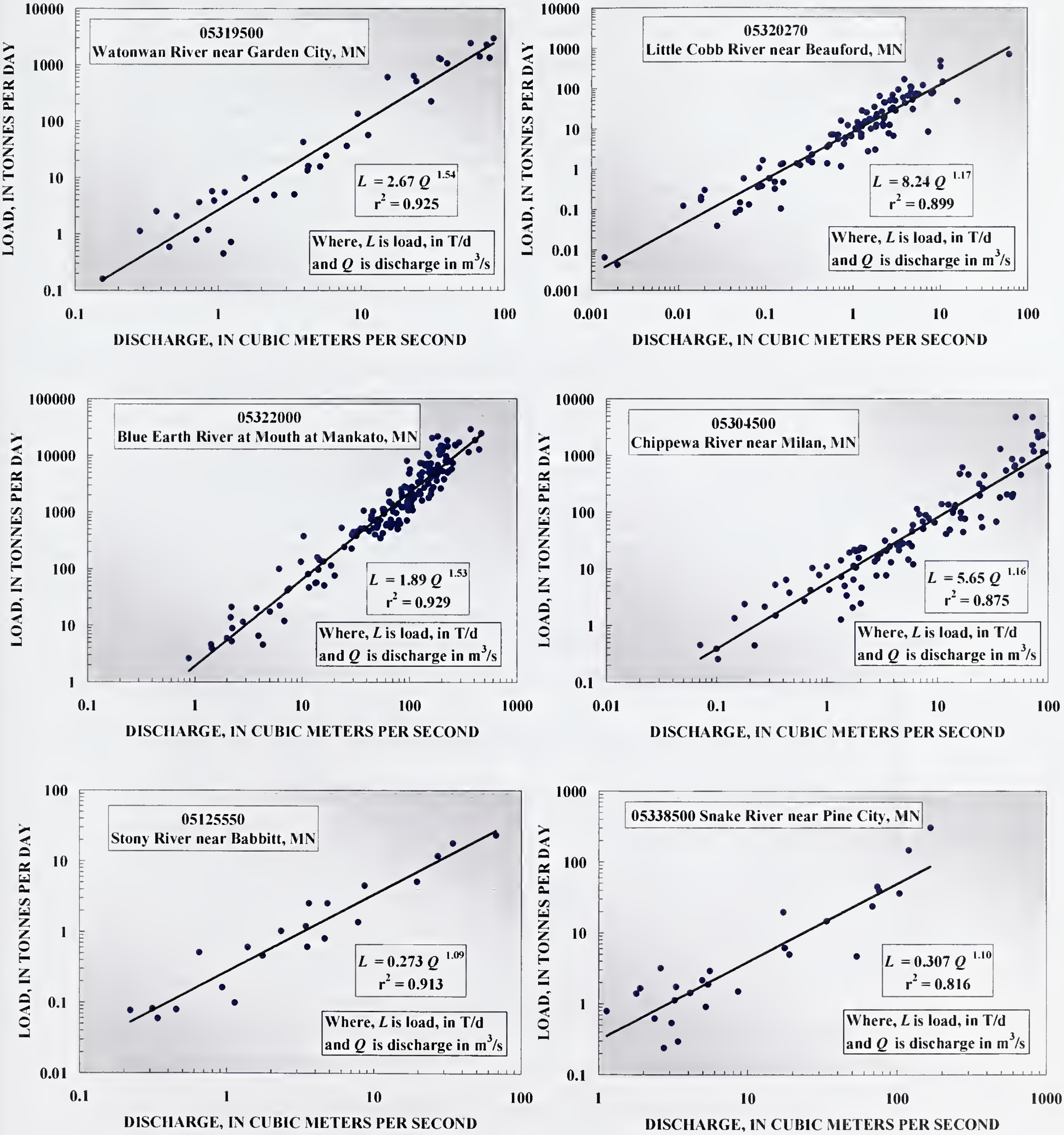


Figure 2 – Rating equations for various gaging stations in Minnesota.

Using storm event data concerning discharge and load, a suspended-sediment transport rating equation was developed for each gaging station (Porterfield, 1972; Glysson, 1987; Simon, 1989). Discharge was plotted against load in log-log space and a power function obtained by regression (Figure 2). In studies carried out in other ecoregions across the United States, trends of these data (in log-log space) often increase linearly and then break off and increase more slowly at high discharges. Preliminary analyses show that although sand concentrations continue to increase with discharge, the silt-clay fraction attenuates, causing the transport relation to flatten (Kuhnle and Simon, 2000). To alleviate this problem, a second (or even third) linear segment (in log-log space) is often fit with the upper end of the dataset (Simon, 1989; Figure 3). The break in slope is determined visually, however 'trend-lines' for each 'set' of data must meet between the datasets.

To examine the validity of using two linear segments (instead of a single power function) to 'predict' suspended-sediment transport at a site, the residuals representing the difference between predicted and observed load values are calculated. An optimum relation would show no trend in the residuals (flat slope). Conversely, a trend in residuals indicates either an under- or over-estimation of load values. This technique was used to determine whether a single, double, or triple segmented relation was to be used for a specific site (Figure 4). Adjustments to the upper end of the rating directly addresses one of Nash's (1994) concerns regarding the use of a single power function to describe the relation between flow and suspended-sediment discharge over the entire range of flows.

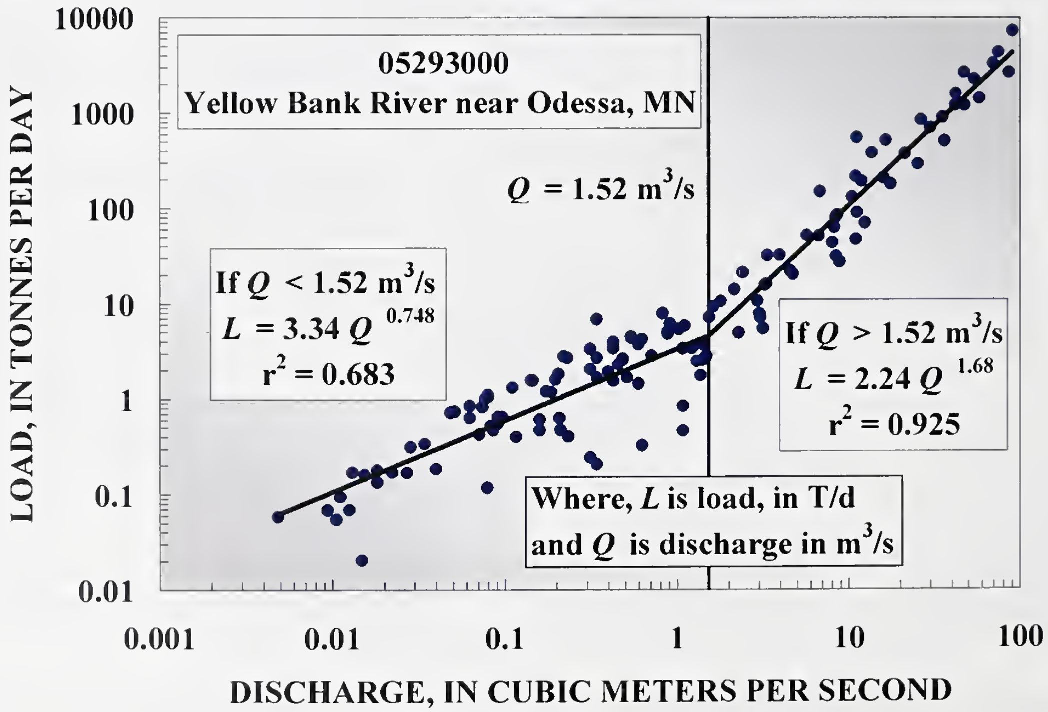


Figure 3 – A rating with two linear segments is used to describe suspended-sediment transport at the Yellow Bank River near Odessa, MN, Ecoregion 46.

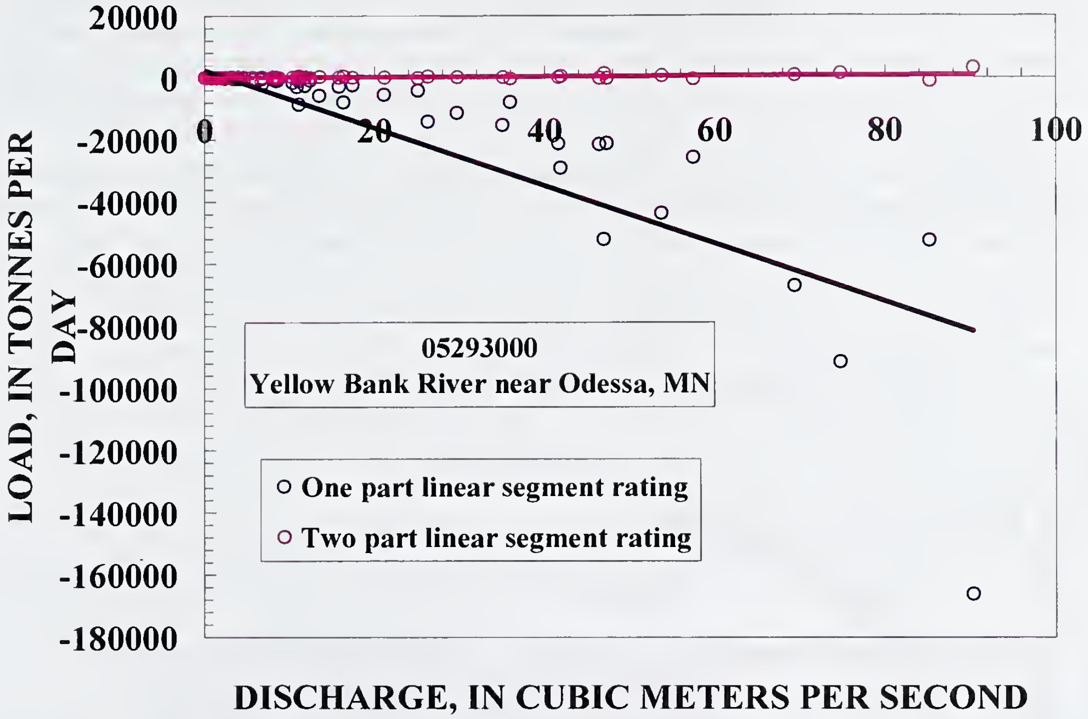


Figure 4 – Load residuals for site 05293000 using a single power function (black line) and with two linear segments (pink line). Note that the trend of residuals using the two-linear segments (Figure 3) is much flatter, indicating a better ‘model’ than the hugely negative trend of residuals using a single power function, which therefore underestimate load values.

4.1.2 Calculating Suspended-Sediment Load at the $Q_{1.5}$

As described in Section 3.1, the $Q_{1.5}$ was used as a surrogate for the effective discharge in this study (Simon *et al.* 2004a). This was calculated from a log-Pearson Type III distribution using the annual-maximum peak-flow series for each of the sites with available data. The example shown in Figure 5 is for the Chippewa River near Milan, MN (Ecoregion 46), where the $Q_{1.5}$ was determined to be 39.5 m^3/s. Suspended-sediment yield at the $Q_{1.5}$ was obtained by using the sediment-transport relation developed for the site (given above in Figure 2), substituting the $Q_{1.5}$ into the relation and solving for load. Dividing by drainage area produces sediment yield (calculations are given in Figure 5). The rating equation was also used to create daily yield values in tonnes per day from mean-daily discharge data. Mean-daily loads were summed for any given *complete* calendar year, providing a mean annual load (T/y). To normalize data for watersheds of different size, sediment load was divided by drainage area, providing calculations of mean annual sediment yield (T/y/km^2). This provides a measure of the annual mass of suspended-sediment transported past a site, per unit of area. Because sediment-transport data is generally non-normally distributed, quartile measures were used to describe data ranges and central tendencies.

As part of the analytic procedure, the maximum sampled discharge is compared to the $Q_{1.5}$ to make sure that it falls within the flow range sampled. If the $Q_{1.5}$ exceeds the maximum sampled discharge by 50%, the site is not used in further analysis. This is because considerable error can occur in calculating loads at high flows, particularly if the sediment-transport relation is extended beyond the measured bounds of the data. In the example shown in Figure 5 for the Chippewa River near Milan, MN, the maximum sampled discharge was 99.4 m^3/s, more than double the calculated $Q_{1.5}$, indicating that the upper-end of the transport relation is relatively well defined.

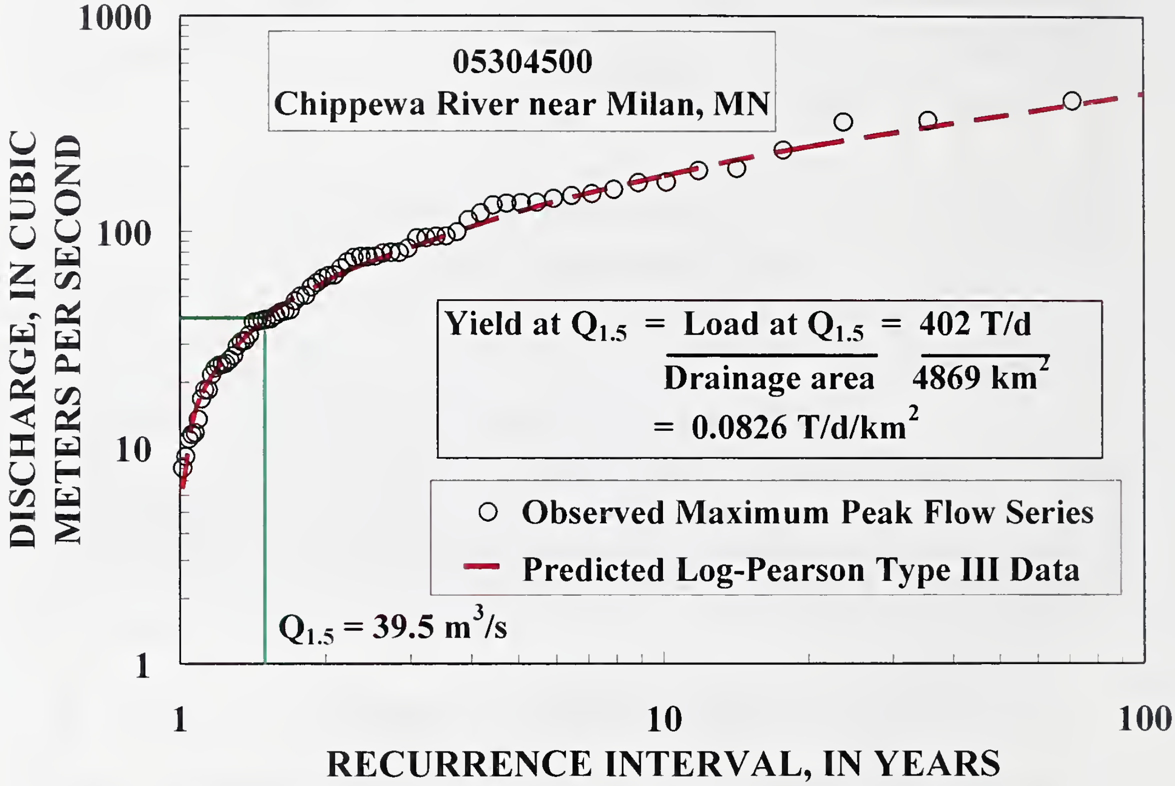


Figure 5 – Flood frequency distribution for the Chippewa River near Milan, MN, Ecoregion 46, as calculated from the annual maximum series. The graph shows predicted values to be a reasonable estimate of observed peak flow measurements. Using the rating equation derived for this site in Figure 2, calculations for suspended-sediment yield are also provided for 05304500, showing a $Q_{1.5}$ yield of 0.0826 m^3/s.

4.1.3 Frequency, Duration and Dosage: Suspended-Sediment Metrics for Potential Analysis with Biotic Data

While both annual and $Q_{1.5}$ suspended-sediment yields are important when considering stream stability and have been used to develop targets for sediment, they may be of little significance to life-cycle processes of aquatic biota found within that stream. In this case it might be more appropriate to consider the frequency of a given concentration and/or

the duration that a given concentration is sustained (Newcombe, *et al.*, 1991; 1996). The hypothesis here is that stable, "reference" streams will have fewer high-concentration events and when those events do occur, they will last for a shorter duration than in unstable streams.

With this in mind, suspended-sediment concentrations (in mg/l) were calculated from mean-daily flow data for each day of flow record. The data were then sorted by daily value and assigned a percentile, based on the complete distribution. A frequency distribution much like the ones typically used to describe flow, based on the percentage of time that given concentrations were equaled or exceeded was then developed for each site. A 99th percentile (exceedance) value represents a very low concentration that is equaled or exceeded 99 percent of the time. Conversely, an exceedance value of 1 represents a relatively high concentration that is exceeded, on average, about 1% of the time. An example is shown from Chippewa River near Milan in Figure 6. Typically, time is given as the constant on the x-axis. However these series of graphs are intended to be used as a tool for practitioners. It is more likely that practitioners will have concentration data available, therefore for ease of application, concentration is on the x-axis.

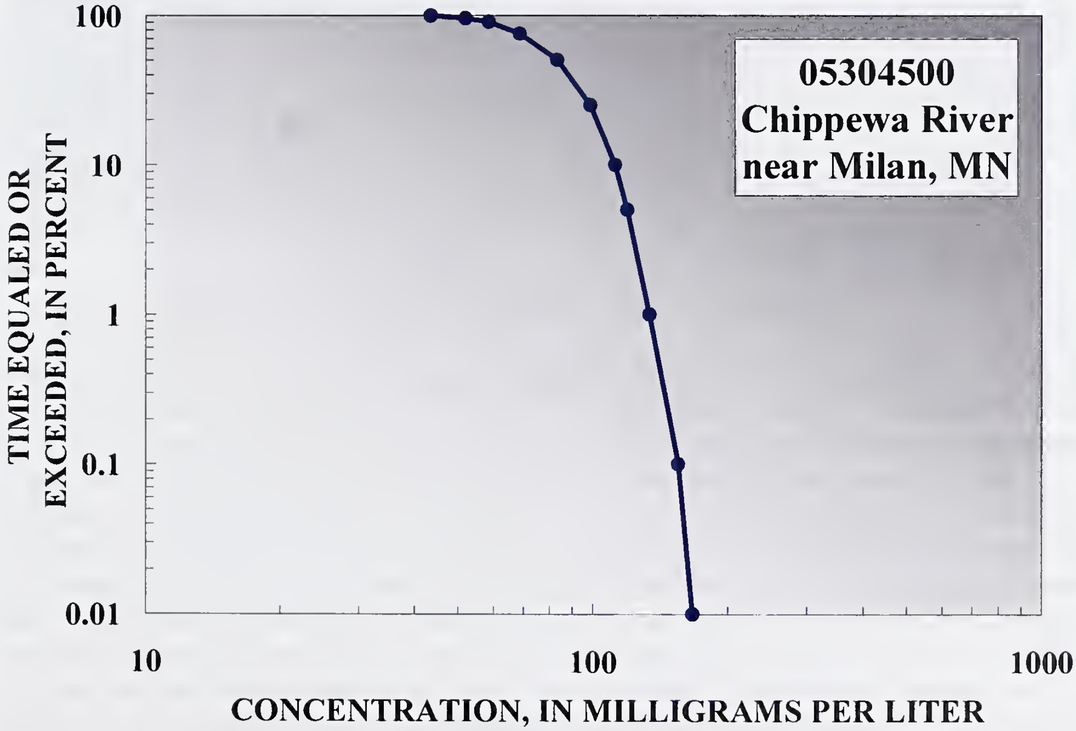


Figure 6 – Example frequency distribution for concentration for the Chippewa River near Milan, MN, showing the percentage of time given concentrations were equaled or exceeded.

To obtain sediment metrics representing the duration a given concentration is maintained or exceeded, a simple macro was created within the spreadsheet database to count the number of *consecutive* days a given concentration was equaled or exceeded (Figure 7).

In this way both magnitude-frequency and magnitude-duration can be examined in terms of geomorphic stability, to test whether concentration frequencies and durations of stable, unimpaired streams can be differentiated from unstable, impacted streams. This was carried out for the period of record for all sites that had sufficient suspended-sediment data (more than 15 samples) and that had more than five complete years of mean-daily flow data.

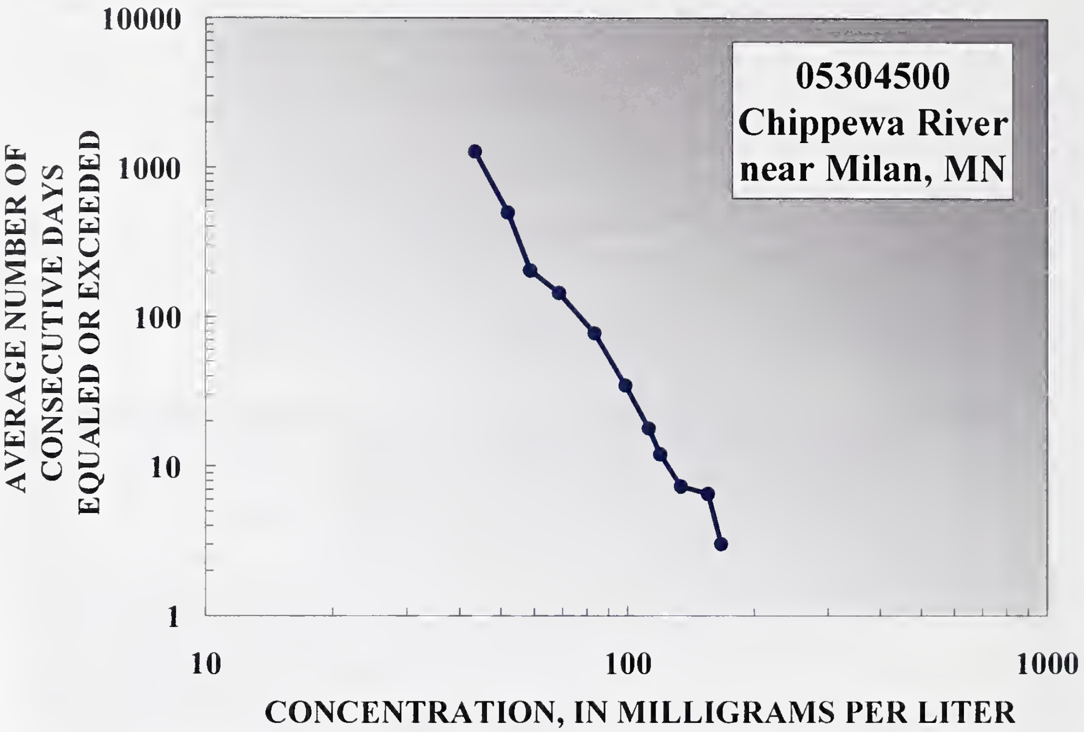


Figure 7 – Magnitude-frequency duration of concentrations for the Chippewa River near Milan, MN. The average number of *consecutive* days a given concentration is equaled or exceeded.

Frequency-magnitude and duration data represents a suspended-sediment dose and frequency of this dose (concentration x duration). Survival of sight-orientated fish insectivores and piscivores could be impacted by frequency of suspended sediment dose. However herbivore and sorting bottom feeders likely would not be impacted by dose. Fish recruitment could be impacted by frequency of suspended-sediment dose if embeddedness is increased for spawners that build gravel nests. However, non-guarding fish spawners that disperse eggs into the open water may benefit from increased suspended sediment dose preventing predators from finding eggs (Schwartz *et al.*, 2009).

The product of sediment concentration and duration that concentration is equaled or exceeded is termed 'dosage' and has been found to be a relevant parameter in studies of the effects of a given pollutant on aquatic biota (USEPA, 2002; Newcombe, 2003; Schwartz *et al.*, in press). Dosage was calculated for the range of concentrations at each site by multiplying a concentration by the number of days of continuous duration. This

was done over the entire range of concentrations and resulted in a distribution for dosage for each site (Figure 8). These dosage distributions were then sorted into stable and unstable sites to differentiate between general differences in sediment dosage by ecoregion. The distribution of differences between ecoregion-level dosages for stable and unstable streams was termed 'dose impact' and provides a means of comparing sediment impacts to biota. In fact, the dosage distribution from an unstable site could be used to evaluate the relative degree of impact by sediment if we consider the dosage distribution for stable streams within an ecoregion as its "reference" condition.

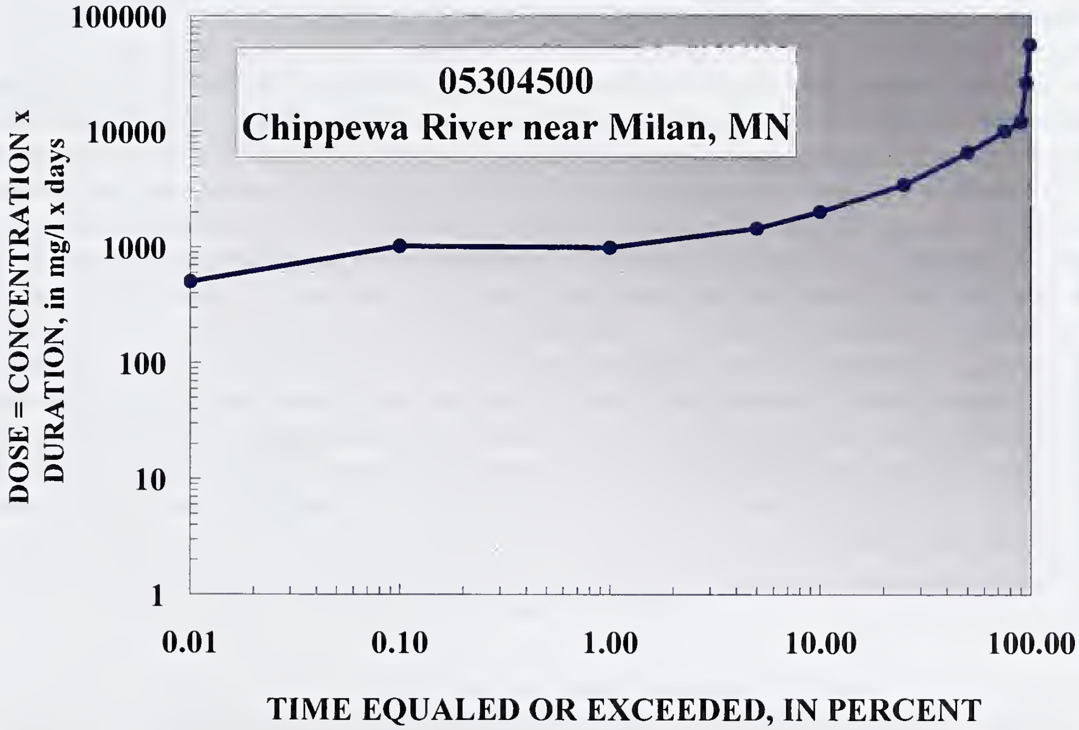


Figure 8 – Concentration dosage calculated for the Chippewa River near Milan, MN by multiplying concentration by the number of continuous days it was equaled or exceeded.

All of the fundamental parameters (metrics) discussed above, whether downloaded and analyzed from historical USGS records or calculated from other available information were compiled into a matrix for each Level III ecoregion within EPA Region 8. These data were then organized to enable further sorting based on relative channel stability, dominant bed-material class, drainage basin area, and in some cases, into Level IV (smaller) Ecoregions.

4.1.4 Trends in Precipitation and Flow over the Past 100 Years

All previously downloaded annual-peak flows and mean-daily flow data were gathered by Level III Ecoregion to examine historical trends in flow and precipitation. Mean-daily flow data for each site were averaged for each year to produce a record of the average annual, mean-daily discharge over time. Results for each year were divided by drainage area to obtain an annual mean-daily 'water yield' so that trends for basins of varying size could be compared for the last 100 years. Appendix A provides the period of mean-daily flow data for each site and the number of complete calendar years of data. This is summarized for each Level III Ecoregion in Table 4.

An average water yield each year was then calculated from all sites within a given ecoregion to produce a region-wide trend over the past century for both mean-daily discharge and the annual peak flow discharge. Trends in water yield over the past 100 years provide a means of integrating the effects of changes in rainfall-runoff regime as a result of climate change and anthropogenic disturbances such as land use changes and dam construction. A similar analysis was conducted using peak-flow data for each site, thereby providing trends in peak water yield for each ecoregion over the last 100 years.

To examine how trends in precipitation may have varied over the past 100 years and how these trends have affected water yields (irrespective of anthropogenic influences), precipitation data across Minnesota was obtained. Monthly precipitation data were summed for each year of record, and an average annual precipitation calculated for each Level III Ecoregion for the period of record (Table 4). Data were also organized by month so that an average precipitation value could be calculated for each month as a time series (for example, January 1900, January 1901, January 1902), and for each month for the period of record.

Table 4 – Number of sites with instantaneous peak flow, mean daily and precipitation data.

Ecoregion	Number of sites with peak flow data	Number of sites with mean daily data	Number of sites with precipitation data
46	29	30	24
47	48	48	45
48	16	14	8
50	30	29	23
51	25	25	14

4.2 Field Data Collection

4.2.1 Establishing Current "Reference" Conditions

Rates and concentrations of suspended-sediment transport vary over time and space due to factors such as precipitation characteristics and discharge, geology, relief, land use and channel stability, among others. There is no reason to assume that 'natural' or background rates of sediment transport will be consistent from one region to another. Within the context of clean-sediment TMDLs, it follows that there is no reason to assume then that 'target' values should be consistent on a nationwide basis. Similarly, there is no reason to assume that channels within a given region will have consistent rates of sediment transport. For example, unstable channel systems or those draining disturbed watersheds will produce and transport more sediment than stable channel systems in the same region. This reflects differences in the magnitude and perhaps type of erosion processes that dominate a sub-watershed or stream reach.

In order to identify those sediment-transport conditions that represent impacted or impaired conditions, it is essential to first be able to define non-disturbed, stable, or "reference" conditions. For the purposes of this study, stability is defined in geomorphic terms; that is, a stream in dynamic equilibrium, capable of transporting all sediment delivered to the system without altering its dimensions over a period of years. This is not to say that the stream is static but that short-term, local processes of scour and fill, erosion and deposition, are balanced through a reach such that the stream does not widen, narrow, degrade or aggrade.

4.2.2 Rapid Geomorphic Assessments: RGA's

To evaluate channel-stability conditions and stage of channel evolution of a particular reach, an RGA was carried out at each site using the Channel-Stability Ranking Scheme. RGAs utilize diagnostic criteria of channel form to infer dominant channel processes and the magnitude of channel instabilities through a series of nine unique criteria. Granted, evaluations of this sort do not include an evaluation of watershed or upland conditions; however, stream channels act as conduits for energy, flow and materials as they move through the watershed and will reflect a balance or imbalance in the delivery of sediment. Given the large number of USGS gages in Ecoregions 46, 47, 48, 50 and 51, it was not feasible to perform detailed, time consuming field surveys at every site, RGAs provided an efficient alternative, enabling the rapid characterization of stability conditions.

Four steps are completed on site:

1. Determine reach. The reach is described as the length of channel covering 6-20 channel widths, thus is scale dependent and covers at least two pool-riffle sequences.
2. Photograph the reach, for quality assurance and quality control purposes. Photographs are used with RGA forms to review the field evaluation
3. Carry out RGA. Make observations of channel conditions and diagnostic criteria listed on the channel-stability ranking scheme (Figure 9).
4. Sample bed material.

CHANNEL-STABILITY RANKING SCHEME

River________________________ Site Identifier________________________

Date ____________ Time________ Crew ______________ Samples Taken____________________

Pictures (circle) U/S D/S X-section Slope__________ Pattern: Meandering / Straight / Braided

1. Primary bed material

	Bedrock	Boulder/Cobble	Gravel	Sand	Silt Clay	
	0	1	2	3	4	_____

2. Bed/bank protection

	Yes	No	(with) 1 bank protected	2 banks		
	0	1	2	3		_____

3. Degree of incision (Relative elevation of "normal" low water; floodplain/terrace @ 100%)

	0-10%	11-25%	26-50%	51-75%	76-100%	
	4	3	2	1	0	_____

4. Degree of constriction (Relative decrease in top-bank width from up to downstream)

	0-10%	11-25%	26-50%	51-75%	76-100%	
	0	1	2	3	4	_____

5. Stream bank erosion (Each bank)

	None	Fluvial	Mass wasting (failures)	
Left	0	1	2	_____
Right	0	1	2	_____

6. Stream bank instability (Percent of each bank failing)

	0-10%	11-25%	26-50%	51-75%	76-100%	
Left	0	0.5	1	1.5	2	_____
Right	0	0.5	1	1.5	2	_____

7. Established riparian woody-vegetative cover (Each bank)

	0-10%	11-25%	26-50%	51-75%	76-100%	
Left	2	1.5	1	0.5	0	_____
Right	2	1.5	1	0.5	0	_____

8. Occurrence of bank accretion (Percent of each bank with fluvial deposition)

	0-10%	11-25%	26-50%	51-75%	76-100%	
Left	2	1.5	1	0.5	0	_____
Right	2	1.5	1	0.5	0	_____

9. Stage of channel evolution

	I	II	III	IV	V	VI	
	0	1	2	4	3	1.5	_____

Figure 9 – Channel stability ranking scheme used to conduct rapid geomorphic assessments (RGAs). The channel stability index is the sum of the values obtained for the nine criterion.

4.2.3 Channel-Stability Index

A scheme that assesses nine unique criteria was used to record observations of field conditions during RGAs (Figure 1). Each criterion was ranked from zero to four and all values summed to provide an index of relative channel stability. The higher the number the greater the instability: sites with values greater than 20 exhibit considerable instability; stable sites generally rank 10 or less. Intermediate values denote reaches of moderate instability. However, rankings are not weighted, thus a site ranked 20 is not twice as unstable as a site ranked 10. The process of filling out the form enables the final decision of 'Stage of Channel Evolution'.

Characterizing Channel Geomorphology

1. Primary bed material

Bedrock	The parent material that underlies all other material. In some cases this becomes exposed at the surface. Bedrock can be recognized by appearing as large slabs of rock, parts of which may be covered by other surficial material.
Boulder/Cobble	All rocks greater than 64 mm median diameter.
Gravel	All particles with a median diameter between 64.0 – 2.00 mm
Sand	All Particles with a median diameter between 2.00 – 0.062 mm
Silt Clay	All fine particles with a median diameter of less than 0.062 mm Grain size classification given by Knighton (1998) p. 107.

2. Bed/bank protection

Yes	Mark if the channel bed is artificially protected, such as with rip rap or concrete.
No	Mark if the channel bed is not artificially protected and is composed of natural material.
1 bank protected	Mark if one bank is artificially protected, such as with rip rap or concrete.
2 banks	Mark if two banks are artificially protected.

3. Degree of incision (Relative elevation of "normal" low water)
Assume top-bank elevation represents the 100% elevation and the thalweg represents 0% elevation, select the relative elevation of "normal" low water.

4. Degree of constriction (Relative decrease in top-bank width from up to downstream)
Often only found where obstructions or artificial protection are present within the channel. Taking the reach length into consideration, channel width at the upstream and downstream parts of the constriction are measured and the relative difference calculated.

5. Stream bank erosion (Each bank)
The dominant form of bank erosion is marked separately for each bank, left and right, facing in a downstream direction.
If the reach is a meandering reach, the banks are viewed in terms of 'Inside, Outside' as opposed to 'Left, Right' (appropriate for questions 5-8). Inside bank, being the inner bank of the meander, if the stream bends to the left as you face downstream, this would be the left bank. Outside bank, being the outer bank, on your right as you face downstream in a stream meandering left.

None	No erosion

Fluvial	Fluvial processes (i.e. undercutting of the bank toe), cause erosion.
Mass Wasting	Mass movement of large amounts of material from the bank is the method of bank erosion. Often characterized by high, steep banks with shear bank faces. Debris at the bank toe appears to have fallen from higher up in the bank face. Includes, rotational slip failures and block failures.

6. Stream bank instability (Percent of each bank failing)
   If the bank exhibits mass wasting, mark percentage of bank with failures over the length of the reach. If more than 50% failures are marked, the dominant process is mass wasting (see question 5).

7. Established riparian woody-vegetative cover (Each bank)
   Riparian vegetative cover refers to perennial vegetation that grows on the streambanks. This was originally defined as including only trees and shrubs but was revised to include perennial grasses.

8. Occurrence of bank accretion (Percent of each bank with fluvial deposition)
   The percentage of the reach length with fluvial deposition of material (often sand, also includes fines and gravels) is marked.

9. Stage of channel evolution
   Stages of channel evolution are given by Simon and Hupp, 1986 (see diagram below). All of the above questions help lead to an answer to this question. Refer to previously determined criterion for guidance. See Table 5 for guidelines of features often found with each stage of channel evolution.

Total Score Total up the responses to the 9 questions.

4.2.4 Stages of Channel Evolution

The channel evolution framework set out by Simon and Hupp (1986) is used by TMDL practitioners to assess the stability of a channel reach (Figure 10; Table 5). With stages of channel evolution tied to discrete channel processes and not strictly to specific channel shapes, they have been successfully used to describe systematic channel-adjustment processes over time and space in diverse environments, subject to various disturbances such as stream response to: channelization in the Southeast US Coastal Plain (Simon, 1994); volcanic eruptions in the Cascade Mountains (Simon, 1999); and dams in Tuscany, Italy (Rinaldi and Simon, 1998). Because the stages of channel evolution represent shifts in dominant channel processes, they are systematically related to suspended-sediment and bed-material discharge (Simon, 1989; Kuhnle and Simon, 2000), fish-community structure (Knight *et al.*, 1997), rates of channel widening (Simon and Hupp, 1992), and the density and distribution of woody-riparian vegetation (Hupp, 1992).

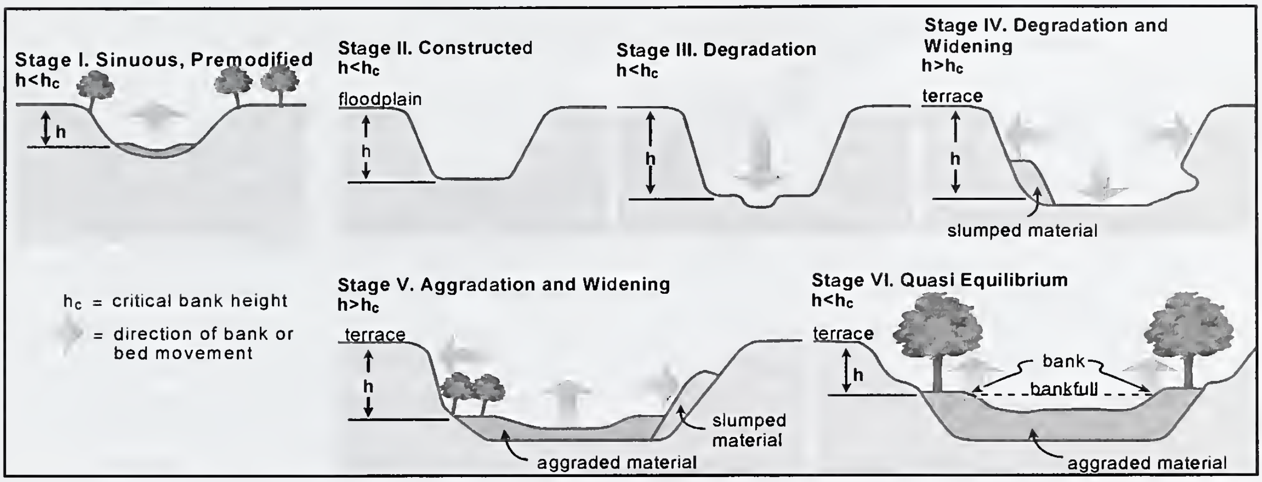


Figure 10 – Six stages of channel evolution from Simon and Hupp (1986) and Simon (1989) identifying Stages I and VI as "reference" channel conditions.

Table 5 – Summary of conditions to be expected at each stage of channel evolution.

Stage	Descriptive Summary
I	*Pre-modified* – Stable bank conditions, no mass wasting, small, low angle bank slopes. Established woody vegetation, convex upper bank, concave lower bank.
II	*Constructed* – Artificial reshaping of existing banks. Vegetation often removed, banks steepened, heightened and made linear.
III	*Degradation* – Lowering of channel bed and consequent increase of bank heights. Incision without widening. Bank toe material removed causing an increase in bank angle.
IV	*Threshold* – Degradation and basal erosion. Incision and active channel widening. Mass wasting from banks and excessive undercutting. Leaning and fallen vegetation. Vertical face may be present.
V	*Aggradation* – Deposition of material on bed, often sand. Widening of channel through bank retreat; no incision. Concave bank profile. Fill material re-worked and deposited. May see floodplain terraces. Channel follows a meandering course.
VI	*Restabilization* – Reduction in bank heights, aggradation of the channel bed. Deposition on the upper bank therefore visibly buried vegetation. Convex shape. May see floodplain terraces.

An advantage of a process-based channel-evolution scheme for use in TMDL development is that Stages I and VI represent true "reference" conditions. In some cases, such as in the Midwestern United States where land clearing activities near the turn of the 20th Century caused massive changes in rainfall-runoff relations and land use, channels are unlikely to recover to Stage I, pre-modified conditions. Stage VI, a re-stabilized condition, is a much more likely target under present regional land use and altered hydrologic regimes (Simon and Rinaldi, 2000) and can be used as a "reference" condition. Stage VI streams can be characterized as a 'channel-within-a-channel', where the previous floodplain surface is less frequently inundated and can be described as a terrace. This morphology is typical of recovering and re-stabilized stream systems following incision. In pristine areas, where disturbances have not occurred or where they are far less severe, Stage I conditions can be appropriate as a reference.

4.2.5 Determining Historical Channel Stability

Unfortunately, it is not uncommon that suspended-sediment sampling was carried out over fifty years ago. Therefore it may be the case that current channel stability was not relevant at the time of suspended-sediment sampling. Plotting certain stream morphology characteristics against a range of discharges over time can help us to establish channel stability during the period of suspended-sediment sampling, as it is both expensive and time consuming to establish current transport-ratings. Figures 11, 12 and 13 provide examples of using USGS stream-flow measurements to estimate channel stability at time of suspended-sediment sampling (examples are not specific to Minnesota as much of the suspended-sediment sampling carried out in Minnesota was relatively recent and there was little need for this analysis at sites within Minnesota specifically). A 2007 RGA judged the channel at station 05114000 on the Souris River near Sherwood, ND to be unstable. Stream-flow measurement data was analyzed for this site as suspended-sediment sampling was carried out between 1974 and 1981, therefore current stability conditions of this channel may mean very little to the stability conditions twenty to thirty years ago. Analysis of stream-flow measurement data shows no bed movement during the time of suspended-sediment sampling, thus this channel is considered stable during that period. Stream-flow data can be used to show no change in channel morphology with time, to show degradation or aggradation, or to show the dynamic nature of a given channel; Figure 12 illustrates channel bed degradation on the Des Moines River, and Figure 13 shows degradation between 1950 and the mid-1980s in Old Mans Creek, the channel then filled and begun to degrade again from the late 1980s to present.

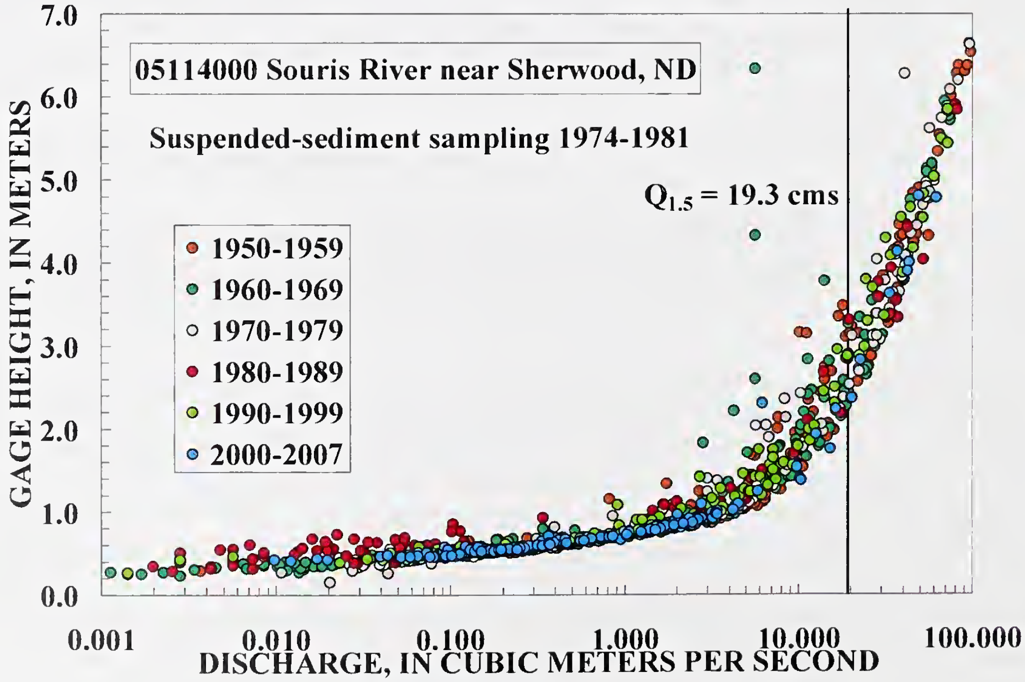


Figure 11 – Stream-flow measurement data for the Souris River near Sherwood, ND show almost no changes in bed elevation during the period of suspended-sediment sampling, suggesting a stable channel at this time.

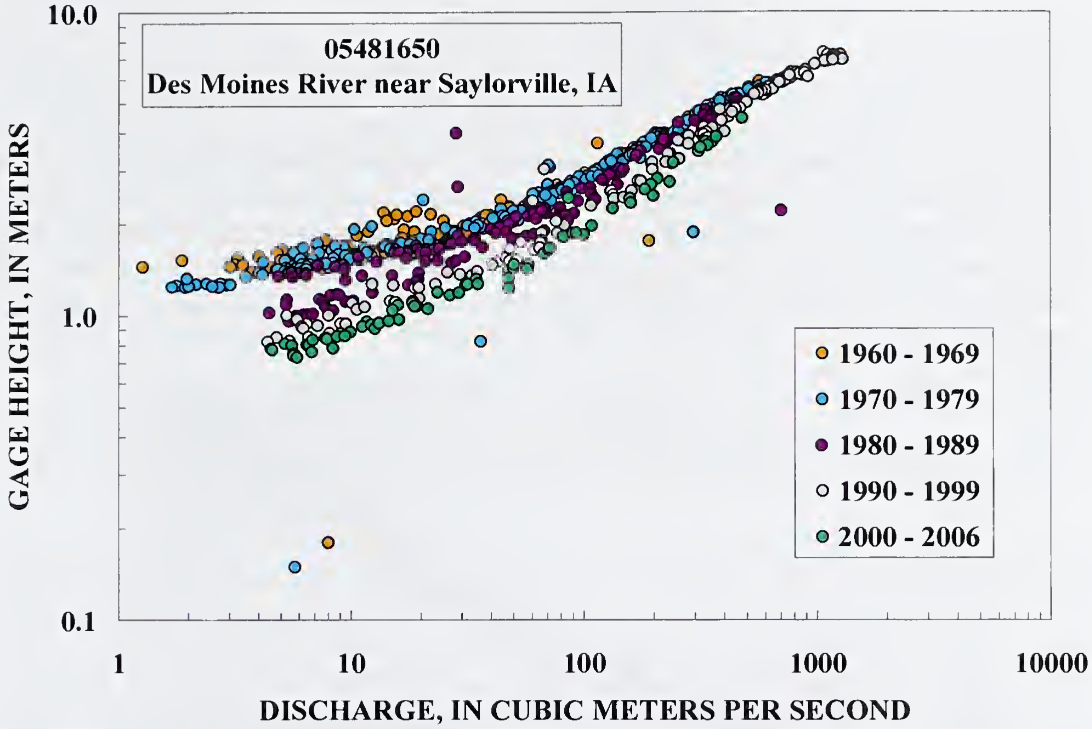


Figure 12 – Des Moines River near Saylorville, IA, Ecoregion 47, stream-flow measurements show continual channel bed degradation since the 1960s.

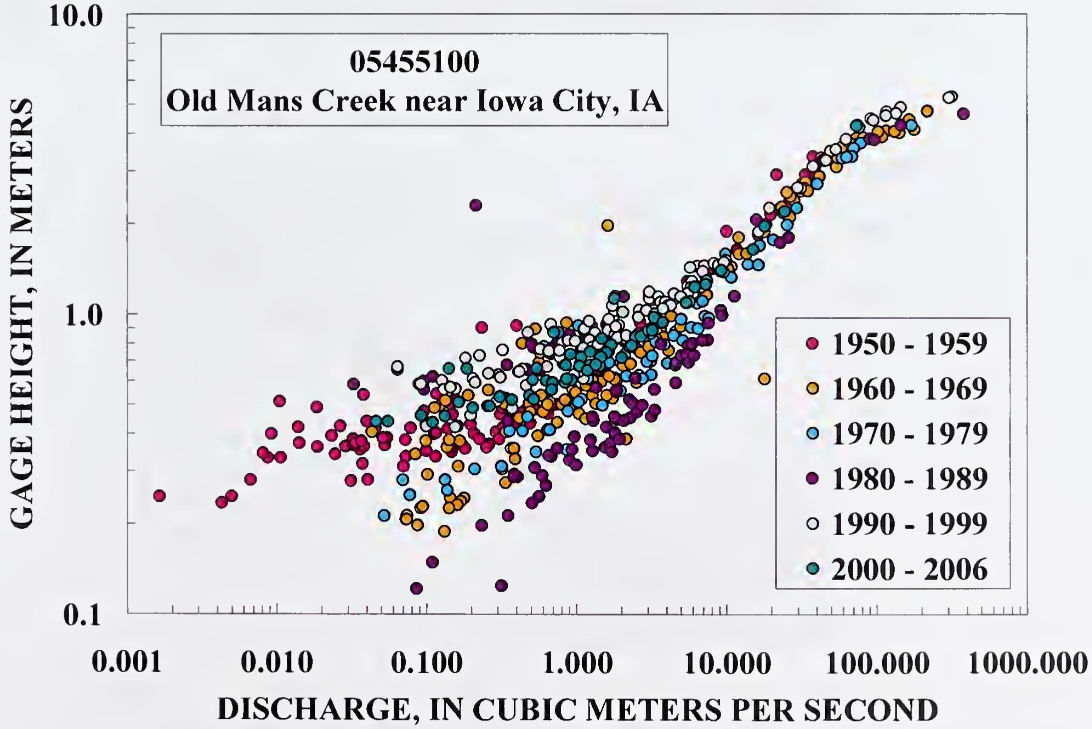


Figure 13 – Stream-flow measurements for Old Mans Creek, IA, Ecoregion 47, show channel degradation between 1950 and the mid-1980s, at which point there was channel filling. Degradation occurred again after the influx of sediment, between the late 1980s and present.

Another method of determining historical stability is to examine suspended-sediment sample data over a range of years, where long periods of record exist. For example, suspended-sediment was sampled between 1970 and 2005 at the Big Sioux River at Akron, IA, Ecoregion 47. Analyzing the suspended-sediment data by decade shows a gradual increase in rating exponent with time from a relatively stable 1.24 to 1.73 (Figure 14a). Such changes in rating relations implies channel adjustments with time, causing a general increase in sediment transport rates as the lines becomes steeper. Shifts in ratings with time can also indicate channel instability; Figure 14b suggests that low flows in the Nodaway River transport lower yields in later sampling years, given by a lower rating coefficient.

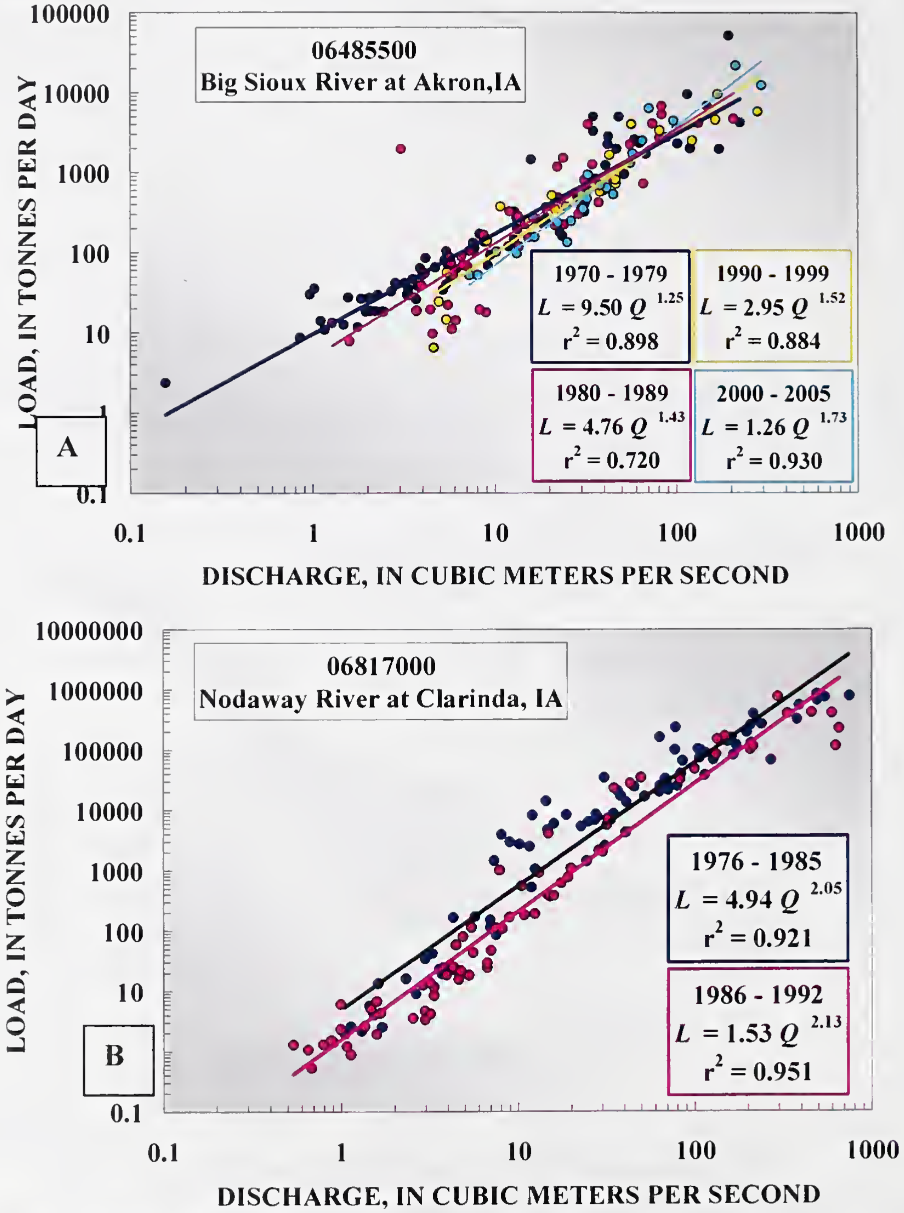


Figure 14 – Changes in suspended-sediment transport relations with time implies channel instability for a) The Big Sioux River and b) The Nodaway River, Ecoregion 47. The reduction in rating coefficient in The Nodaway River transport rating suggests the channel is tending toward stability.

4.2.6 Bed-Material Conditions

As part of each RGA, bed material was characterized. If the bed material was dominated by gravels (2.00 mm or greater) or coarser fractions, a particle count was carried out. For a particle count, the intermediate axis of one hundred particles across the channel was measured, in order to represent a range of different particle sizes found across the width of the bed. Having carried out the particle count, if 16 % of the particles measured, had a median diameter of less than 2 mm, a bulk particle size sample of 100 g or greater was collected from the left, middle and right portions across the channel. This bulk sample was sieved to half-Phi intervals. Particle size data was combined with particle count data to give percentiles of class sizes and values for commonly used metrics such as the median particle size. If fines dominated the bed material, only a bulk sample was taken.

When concerned with water quality issues and their impact upon aquatic biota, the condition of the bed material is a key factor (Roy *et al.*, 2003). One critical bed condition for biota is the filling of interstitial spaces between coarse particles (material 2 mm or larger; gravel, cobbles and boulders) with fines (material smaller than 2 mm; sand, silt and clay). This 'filling of spaces' reduces macro-invertebrate habitat availability, affects insect mobility, feeding and respiration (Minshall, 1984). One way to examine this condition is through the "embeddedness" of the bed material. For this study we defined embeddedness by the percentage of material finer than 2 mm in an otherwise coarse matrix.

5. RESULTS AND DISCUSSION

Using the procedures for developing suspended-sediment transport relations and the $Q_{1.5}$ discharge, values of both mean annual suspended-sediment yield and yield at the $Q_{1.5}$ were obtained for each site with fifteen or more suspended-sediment samples. Suspended-sediment transport data are reported in terms of yields (tonnes/year/km^2 for mean annual yields; and tonnes/day/km^2 for the $Q_{1.5}$), to enable comparison of streams of varying size within ecoregions. Because data for individual ecoregions were often non-normally distributed, quartile measures were used to describe data ranges and central tendencies.

5.1 Relative Channel Stability

The majority of RGAs for the selected Level III Ecoregions were carried out between 2006 and 2007, providing current channel-stability conditions. Some parts of Ecoregion 47 were visited in 2003, however this is still considered 'recent' and used contemporaneously with the data collected in 2006 and 2007. RGA findings are given in Appendix C. In most cases it was appropriate to apply 'current' channel stability conditions to a given site, however suspended-sediment was sampled as early as 1950 at some sites, during which time channel stability may have been different. In situations where it was felt that channel stability at the time of suspended-sediment sampling was different to stability at the time of RGA fieldwork, channel stability was determined using other means, as described in section 4.2.5.

The distribution of channel-stability conditions at USGS gages with sufficient suspended-sediment and associated instantaneous discharge data is provided in Figure 15, with specific stages of channel evolution given in Table 6 by Level III Ecoregion. It is not appropriate to use these values as a basis for channel stability across a given ecoregion, as the sites that these values represent may not be evenly distributed spatially across each ecoregion. It is, however, appropriate to deduce that at the time of suspended-sediment sampling, the majority of sites where a sufficient number of suspended-sediment samples and associated instantaneous discharges were collected in Ecoregion 48, were geomorphically unstable. Almost half of the sites visited in Ecoregion 48 were stage V channels, in which aggradation and widening are the dominant geomorphic processes. Of the sites visited in Ecoregion 48, 67 % were stage V or VI channels; and therefore appear to be 'recovering' from disturbance as aggradation is a dominant process. Channels visited within Ecoregion 47 were also found to be predominantly unstable, with 76 % of the channels either stage V or VI, and therefore in a 'post-disturbance recovery' phase.

In contrast to Ecoregions 47 and 48, the majority of channels visited within Ecoregions 46, 50 and 51 were found to be stable channels. Similar relative frequencies of Ecoregion 50 and 51 channels were determined to be pre-modified channels (stage I, 35 and 34 % respectively), possibly a function of bed material at these locations (most of the channels determined to be stage I in Ecoregion 50 were dominated by a coarse bed material, whilst those in Ecoregion 51 appear to be more wetland type environments, Figure 16). It is however important to consider that these values represent only channels with USGS gages where a sufficient number of suspended-sediment samples were collected.

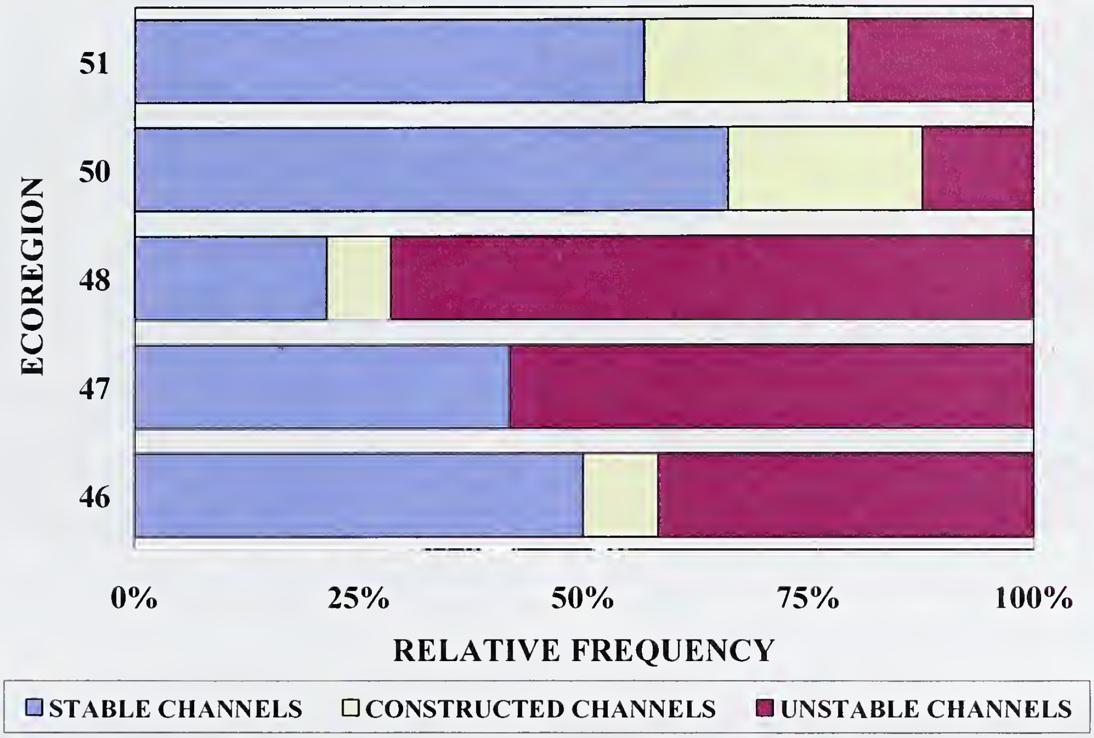
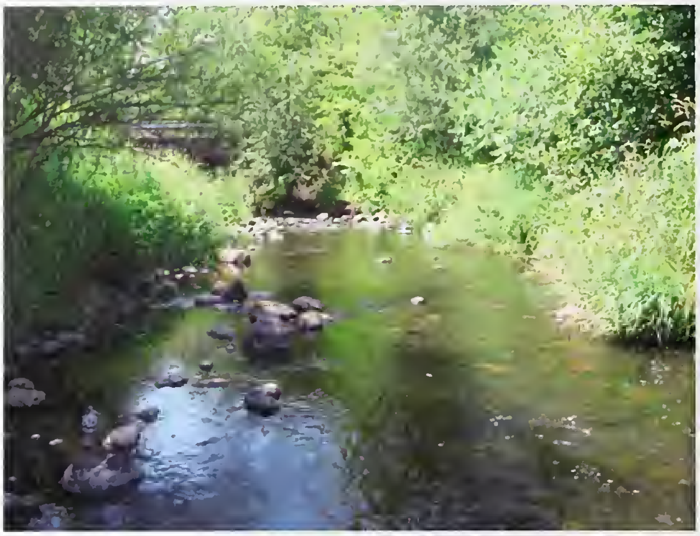


Figure 15 – Relative frequency of channel stability by Level III Ecoregion. Note: stable channels are stages I and VI; constructed channels are stage II; and unstable channels are represented by stages III, IV, and V.

Table 6 – Relative channel stability at time of suspended-sediment sampling for Level III Ecoregions of Minnesota. Bold values represent the majority.

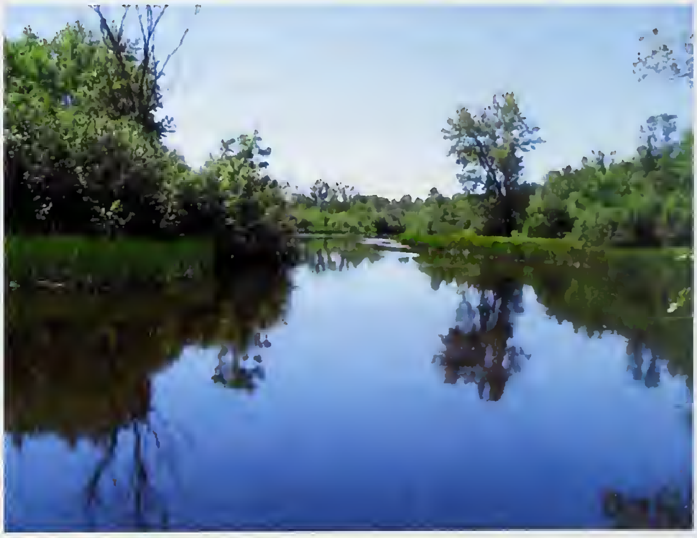
Relative channel stability		Relative frequency of channel stability at time of suspended-sediment sampling				
		46	47	48	50	51
I	Pre-modified	16.7	9.1	5.6	35.4	34.1
II	Constructed	8.3	0.0	5.6	21.5	22.7
III	Degradational	0.0	9.1	5.6	1.5	4.5
IV	Threshold	0.0	5.5	16.7	0.0	0.0
V	Aggradational	41.7	43.6	44.4	10.8	15.9
VI	Re-stabilization	33.3	32.7	22.2	30.8	22.7
STABLE (Stages I and VI)		**50.0**	41.8	21.4	**66.2**	**56.8**
UNSTABLE (Stages III, IV and V)		41.7	**58.2**	**71.4**	12.3	20.5
CONSRUCTED (Stage II)		8.3	0.0	7.1	21.5	22.7
Number		36	62	14	68	44



05367190 Hemlock Creek at Country Trunk HWY F near Mikana, WI. Ecoregion 50

05125550 Stony River at Babbit, MN. Ecoregion 50

05403630 Hulbert Creek near Wisconsin Dells, WI. Ecoregion 51



04077630 Red River at Morgan Road near Morgan, WI. Ecoregion 51

Figure 16 – Pre-modified, stage I channels in Ecoregion 50 dominated by coarse bed matrix (TOP) and wetland-type stage I channels in Ecoregion 51 (BOTTOM).

Another way to use physical data collected in the field as part of the RGA is to observe the channel stability index, the sum of the nine criteria from the RGA form. In contrast to the results given above for relative channel stability in terms of the Stage of Channel Evolution Model, channel stability indices are given at time of RGA for Level III Ecoregions in Figure 17 and Table 7, therefore not necessarily at time of suspended-sediment sampling. A range of stability index scores applies to each stage of channel evolution. A stage V channel, for example, can have a channel stability index of between 12 and in the mid-20s, therefore there are different degrees of instability. Generally a score below 10 represents a stable site, while one above 20 is extremely unstable.

A function of all geomorphic channel features, patterns in channel stability index scores are similar to those for stability. Ecoregion 48 has the highest relative proportion of extremely unstable channels, with over half of the channels visited scoring above 20. Figure 18 illustrates bank mass failures common at many Ecoregion 48 sites. Both Ecoregions 50 and 51 have the highest proportions of channels scoring under 10 (72 and 61 % respectively), in the stable channel range, very few channels scoring between 15 and 25, and unlike channels in Ecoregions 46, 47, and 48, no extremely unstable channels that score over 25 in the channel stability ranking scheme.

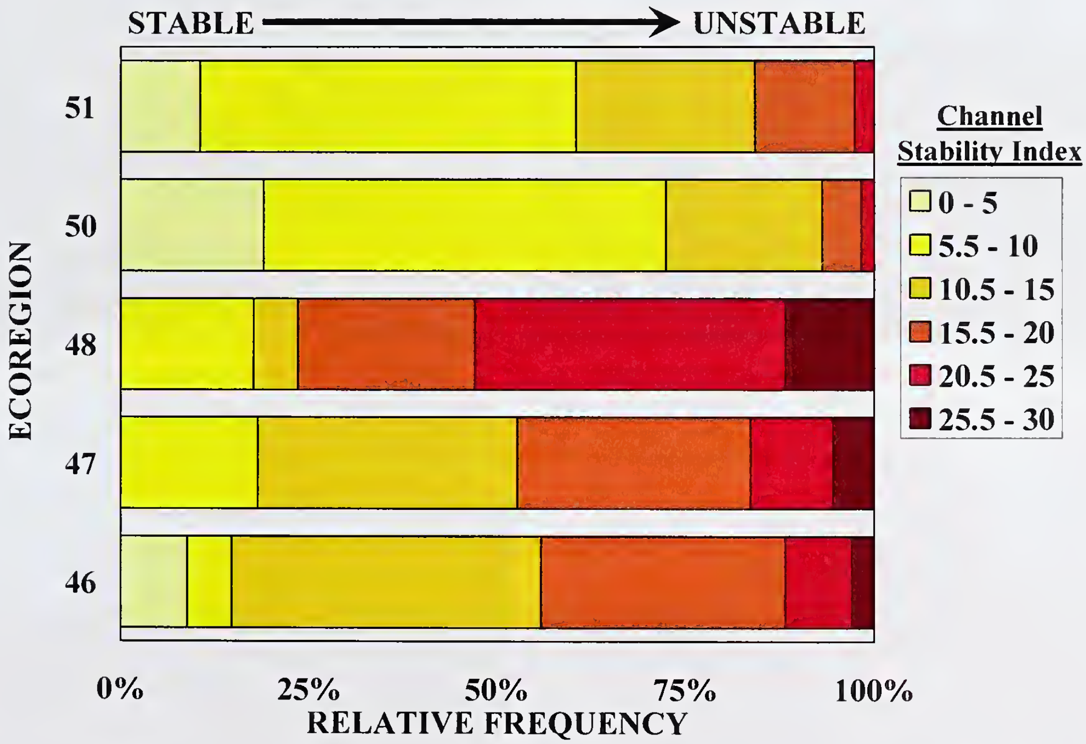


Figure 17 – Channel stability index scores are the sum of the nine Rapid Geomorphic Assessment criteria. Low values (< 10) represent stable channels, high values (> 20) represent unstable channels. Scoring is objective, however a channel scoring 20 on the index is not twice as unstable as a channel that scores 10.

Table 7 – Channel stability index scores at time of Rapid Geomorphic Assessment for Level III Ecoregions of Minnesota. Values less than 10 are generally considered stable channels; those over 20 are extremely unstable.

Channel stability index	Relative frequency of channel stability index at time of Rapid Geomorphic Assessment				
	46	47	48	50	51
0 - 5	8.8	0.0	0.0	19.0	10.5
5.5 - 10	5.9	18.2	17.6	53.4	50.0
10.5 - 15	41.2	34.5	5.9	20.7	23.7
15.5 - 20	32.4	30.9	23.5	5.2	13.2
20.5 - 25	8.8	10.9	41.2	1.7	2.6
25.5 - 30	2.9	5.5	11.8	0.0	0.0

05059000 Sheyenne River near Kindred, ND

05062500 Wild Rice River at Ton Valley, MN

05083500 Red River of the North at Halstad, MN

05099600 Pembina River at Walhalla, ND

Figure 18 – Examples of mass bank failure features common to many sites located in Ecoregion 48.

5.2 Bed-Material Characteristics

As part of the RGA carried out at each site, bed material was sampled and a field estimate of dominant bed material determined. In all five Level III Ecoregions, channel beds were dominated by sand (0.063 – 2 mm, Table 8). Ecoregions 50 and 51 had higher numbers of coarse grained (greater than 2 mm median diameter) dominated bed material (29 and 18 respectively) than in other Ecoregions which each had less than 11 sites visited with a coarse dominant bed material. In cases where bed material was dominated by a coarse matrix, with a median particle diameter greater than 2 mm, embeddedness was calculated. Embeddedness is the percentage of fine material (less than 2 mm median particle diameter) present in an otherwise coarse dominant bed material matrix and is useful as an indicator of habitat quality for fish (Kondolf *et al.*,2003). Embeddedness values were separated by relative channel stability to provide a "reference" embeddedness value for Ecoregions 46, 50 and 51 (Table 9). It is essential to note the number of sites embeddedness values were calculated from in Table 9, as this will dictate the 'reliability' of the data (just four sites in the case of Ecoregion 46). Embeddedness values are not provided for Ecoregions 47 or 48 as there were just two stable channels with a dominant coarse bed matrix in Ecoregion 47, and none in Ecoregion 48. Values of fine material within a coarse matrix were greater in unstable channels than for stable in all three Ecoregions where such values could be calculated.

Table 8 – Number of sites with a given dominant bed material for each Level III Ecoregion in Minnesota.

Median particle diameter in mm	Size class	Number of sites within each Level III Ecoregion with dominant bed material				
		46	47	48	50	51
> 65	Boulder/cobble*	2	2	0	11	6
2 - 65	Gravel	8	10	3	18	12
0.063 - 2	Sand	**24**	**43**	**10**	**25**	**14**
< 0.063	Silt/clay	1	0	0	0	0

* Includes bedrock dominated channel beds. In cases where water was too deep or swift, boulder/cobble dominated channels were not sampled.

When placed in context with "reference" embeddedness values from other Level III Ecoregions across the United States, Ecoregions 50 and 51 values are reasonably similar to that of Ecoregion 43, The Northwestern Glaciated Plains (Table 10). Ecoregion 46 embeddedness "reference" value is lower, similar to that of adjacent Ecoregion 42, however both of these values are calculated from just four stable sites with a coarse dominated bed material, and therefore should be used cautiously. An embeddedness standard of 10% was determined by Hausle and Coble (1976) for Brook trout based on the percent of bed material finer than 2mm. Others, using 0.83 mm as the fine-sediment discriminator, found standards ranging from 7.5% to 21%, with an average of 13.7% (Kondolf *et al.*, 2003). Thus, values obtained in this report appear to be reasonable.

Table 9 – Embeddedness values by Level III Ecoregion within Minnesota; calculated as the percentage of fine material in a coarse dominated bed material. Note the number of sites used to calculate a given value.

PERCENT FINES WITHIN COARSE DOMINATED CHANNELS (< 2 mm median diameter)						
	Ecoregion 46		Ecoregion 50		Ecoregion 51	
	STABLE CHANNELS	UNSTABLE CHANNELS	STABLE CHANNELS	UNSTABLE CHANNELS	STABLE CHANNELS	UNSTABLE CHANNELS
10th Percentile	1.38	3.60	0.00		2.00	7.80
25th Percentile	**3.44**	**9.00**	**3.00**		**4.00**	**12.0**
50th percentile	**4.80**	**10.5**	**8.00**		**9.89**	**21.7**
75th Percentile	**9.37**	**16.0**	**22.0**		**28.0**	**24.0**
90th Percentile	17.2	19.0	36.4		30.8	30.5
Number	4	5	25	1	13	5

Table 10 – "Reference" embeddedness values for ecoregions in Minnesota compared to values from other locations; calculated as the percent of fine material (< 2.00 mm median diameter) in a coarse grained (> 2.00 mm median diameter)dominated bed material in *stable* channels.

Ecoregion number and name	"Reference" embeddedness value	Number of sites used to calculate embeddedness	Source
15: Northern Rockies	2%	7	Simon *et al.*, 2008
17: Middle Rockies	2%	27	Simon *et al.*, 2008
22: Arizona/New Mexico Plateau	16%	14	Heins *et al.*, 2004
42: Northwestern Glaciated Plains	5%	4	Simon *et al.*, 2008
43: Northwestern Great Plains	11%	18	Simon *et al.*, 2008
46: Northern Glaciated Plains	5%	4	This study
50: Northern Lakes and Forests	8%	25	This study
51: North Central Hardwood Forest	10%	13	This study
65: Southeastern Plains	19%	10	Klimetz and Simon, 2006.
67: Ridge and Valley	4%	26	Simon *et al.*, 2004b

5.3 Suspended-Sediment Yields at the 1.5-Year Recurrence Interval Discharge

"Reference" or 'target' values for suspended-sediment yield at the $Q_{1.5}$ (based on the median value of *stable* channels) ranged over two orders of magnitude, from 0.0039 T/d/km^2 in Ecoregion 46 to 0.480 T/d/km^2 in Ecoregion 47 (Table 11). Median, suspended-sediment yields at the $Q_{1.5}$ for unstable sites were generally at least an order of magnitude greater than stable or "reference" values for each of the Level III Ecoregions for which suspended-sediment transport was calculated (Figure 19). The results shown in Figure 21 are plotted using the same scale on the ordinate for each ecoregion, to make comparisons easier. Stable channel 90th percentile values are greater in Ecoregion 51, than for unstable channels, a result of two anomalous stable sites on the Kewaunee and Hay Rivers which both have a comparatively high $Q_{1.5}$ yield of 1.2 T/d/km^2. There is also one anomalous stable site in Ecoregion 50 with a large $Q_{1.5}$ yield of 3.43 T/d/km^2, the Ontagon River near Rockland, MI (#0404000), however this river has tall side-slopes adjacent to the channel which may contribute sediment during high flow events.

Table 11 – Suspended-sediment yield quartile values at the $Q_{1.5}$ for all, stable and unstable sites. Note the number of sites used to calculate percentile values. Bold black values represent the inter-quartile range; bold red values represent the median value.

ALL SITES

	Suspended-sediment yield at $Q_{1.5}$ in T/d/km^2				
	46	**47**	**48**	**50**	**51**
10th Percentile	0.00164	0.144	0.0261	0.0106	0.0155
25th Percentile	**0.00357**	**0.359**	**0.0529**	**0.0211**	**0.0370**
50th Percentile	**0.00831**	**1.57**	**0.0850**	**0.0505**	**0.0714**
75th Percentile	**0.202**	**34.1**	**0.213**	**0.194**	**0.169**
90th Percentile	0.572	102	0.306	1.80	0.598
Number	37	49	14	31	25

STABLE SITES

	Suspended-sediment yield at $Q_{1.5}$ in T/d/km^2				
	46	**47**	**48**	**50**	**51**
10th Percentile	0.00124	0.0911	0.02539	0.0111	0.0125
25th Percentile	**0.00233**	**0.178**	**0.0335**	**0.0203**	**0.0303**
50th Percentile	**0.00393**	**0.480**	**0.0602**	**0.0350**	**0.0441**
75th Percentile	**0.00831**	**1.36**	**0.0837**	**0.0729**	**0.149**
90th Percentile	0.131	3.28	0.0860	0.143	1.06
Number	17	19	4	19	12

UNSTABLE SITES

	Suspended-sediment yield at $Q_{1.5}$ in T/d/km^2				
	46	**47**	**48**	**50**	**51**
10th Percentile	0.00210	0.317	0.0607	0.320	0.0873
25th Percentile	**0.0142**	**1.42**	**0.0704**	**0.616**	**0.100**
50th Percentile	**0.0768**	**41.9**	**0.177**	**1.11**	**0.162**
75th Percentile	**0.304**	**95.4**	**0.288**	**3.43**	**0.224**
90th Percentile	0.664	444	0.334	4.8	0.471
Number	14	24	9	3	7

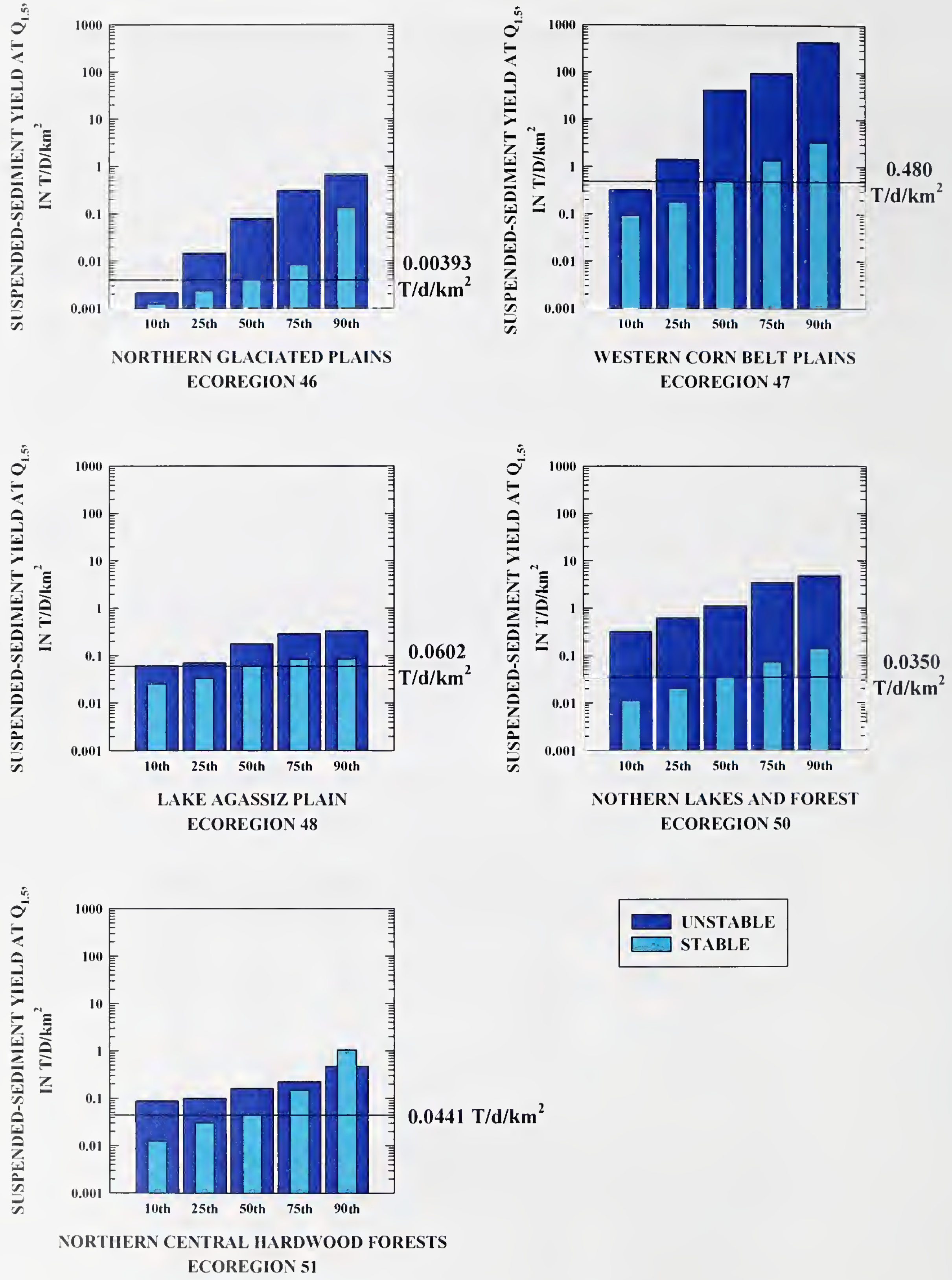


Figure 19 – "Reference" suspended-sediment yield (horizontal lines) and quartile values at the $Q_{1.5}$ for both stable (light blue) and unstable (dark blue) channels.

Due to the substantial range of suspended-sediment yield values and the uncertainty inherent in regionalizing these data, it may be more appropriate to consider ranges in "reference" values as opposed to utilizing only the median value. In work with other cooperators and stakeholders based on previous studies, the inter-quartile range is often used as the 'target'. These values are shown for each Level III Ecoregion in bold in Table 11, above. For example, the 'target' range for Ecoregion 46 is from 0.00233 to 0.00831 T/d/km^2 at the $Q_{1.5}$. The variation in inter-quartile ranges for all of the ecoregions can be clearly seen in Figure 20. Ecoregion 47 has the largest inter-quartile range of "reference" values from 0.178 to 1.36 T/d/km^2, which may be related to variable hydrologic, topographic, and geologic conditions within the vast area encompassed by Ecoregion 47; from Minnesota in the north, to Kansas in the south.

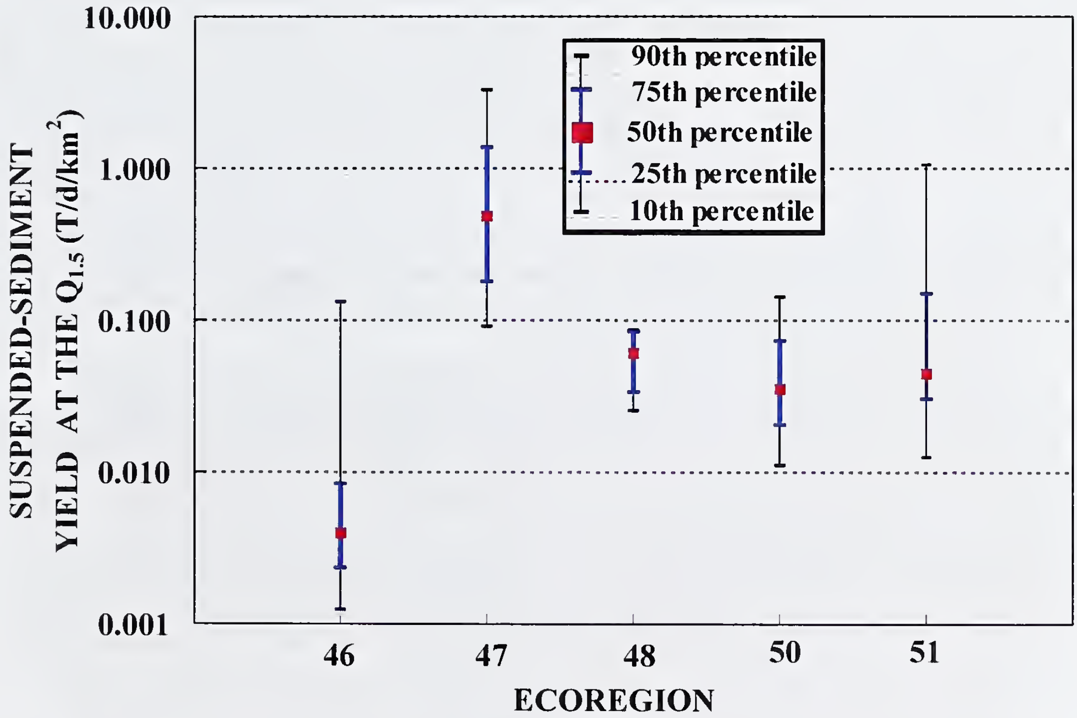


Figure 20 – Variations in "reference" suspended-sediment yield and quartile values at the $Q_{1.5}$ between Level III Ecoregions in Minnesota.

In comparison to ecoregions in other parts of the country, "reference" suspended-sediment yield values at the $Q_{1.5}$ are relatively low in Minnesota. "Reference" $Q_{1.5}$ suspended-sediment yield values for Ecoregions 46, 50, and 51 are close to coastal-plain areas in the southeastern United States (Ecoregions 63 and 75: 0.0313 and 0.0379 T/d/km^2, respectively; Klimetz and Simon, 2006). While Ecoregion 47 has the 'highest' $Q_{1.5}$ "reference" yield values in Minnesota and surrounding areas (at least an order of magnitude greater than Ecoregions 46, 48, 50 and 51), it still has a lower Q1.5 yield value than all but three Ecoregions of EPA Region 4 (coastal areas and Ecoregion 65). Higher

"reference" $Q_{1.5}$ yield values in Ecoregion 47 may be a result of the intensive agricultural land that typifies the region ("over 75 % of the Western Corn Belt Plains is now used for cropland agriculture and much of the remainder is in forage for livestock", EPA 2002b). Low gradient channels throughout the flat to gently rolling landscape of the Northern Glaciated Plains, Ecoregion 46, are likely to be the major reason for such low transport rates. Even unstable channels in Ecoregion 46 transport especially low rates of suspended-sediment. The many lakes located in the Northern Lakes and Forests (Ecoregion 50) and North Central Hardwood Forest (Ecoregion 51) may act as sediment-traps, the slow moving waters of the wetlands reducing the transport of suspended-sediment and the highly vegetated forested areas providing support to the poor glacial soils.

To test for the validity of the overall approach of determining "reference" transport rates at the $Q_{1.5}$ (and later as annual values) by differentiating between geomorphically stable and unstable channels, statistical tests to compare data distributions within each ecoregion were conducted. If the data distribution was determined to be normally distributed, a t-test of the means was carried out. For non-normally distributed data, the Mann-Whitney rank sum test was used to compare median values. For each of the ecoregions studied, it was found that "reference" sediment yields at the $Q_{1.5}$ were significantly different (p-value < 0.05) than the unstable channel sediment yields within the same Level III Ecoregion, except for Ecoregion 51 $Q_{1.5}$ values (Table 12). The Mann-Whitney Rank Sum Test was re-run having removed two major outliers from the stable sites data set. Stable and unstable sites were then found to be statistically significantly different, with a P-value of 0.007.

Table 12 – Tests of statistically significant differences for suspended-sediment yields at the $Q_{1.5}$ between stable and unstable channels in the studied Level III Ecoregions.

		$Q_{1.5}$ yields			
Level III Ecoregion	**Statistically significant difference between stable and unstable yield values**	**Normally distributed**	**Stable n**	**Unstable n**	**P value**
46	Yes	No	17	13	0.027
47	Yes	No	19	24	< 0.001
48	Yes	Yes	4	9	0.025
50	Yes	No	3	19	0.022
51	No	No	7	12	0.083

5.4 Mean Annual Suspended-Sediment Yields

Mean annual suspended-sediment yields vary by more than an order of magnitude across the ecoregions of Minnesota; ranging from 0.579 $T/y/km^2$ in Ecoregion 46 to 50.6 $T/y/km^2$ in Ecoregion 47 (Table 13). "Reference" mean annual suspended-sediment yields show a similar range with stable streams in Ecoregion 46 producing 0.351 $T/y/km^2$ while stable streams produce 20.3 $T/y/km^2$ in Ecoregion 47 (Table 13, Figure 21). Median values for unstable streams were an order of magnitude greater than for stable or "reference" values in Ecoregions 46, 47 and 50, and while still greater in Ecoregions 48 and 51, not an order of magnitude greater. There is some alteration in the ranking of Ecoregions by annual and $Q_{1.5}$ yield "reference" values. However, Ecoregion 47 "reference" channels transport the largest amount of suspended-sediment both annually and during effective discharge events. Ecoregion 47 "reference" channels also exhibit the greatest inter-quartile ranges, implying more disparity between 'stable' channels. Ecoregion 46 mean annual and $Q_{1.5}$ suspended-sediment yields are the lowest in the region with a much smaller inter-quartile range. The variation in mean annual suspended-sediment yield inter-quartile ranges for all of the ecoregions can be seen clearly in Figure 22.

Table 13 – Mean annual suspended-sediment yield values for all, stable and unstable sites. Note the number of sites used to calculate percentile values. Bold black values represent the inter-quartile range; bold red values represent the median value.

ALL SITES					
	Mean annual suspended-sediment yield in $T/y/km^2$				
	46	47	48	50	51
10th Percentile	0.0748	8.43	1.20	0.878	1.29
25th Percentile	**0.210**	**17.8**	**1.96**	**1.16**	**1.87**
50th Percentile	**0.579**	**50.6**	**5.23**	**1.91**	**3.31**
75th Percentile	**5.18**	**255**	**8.81**	**6.11**	**5.22**
90th Percentile	7.86	592	15.0	35.6	8.86
Number	27	48	13	30	25

STABLE SITES					
	Mean annual suspended-sediment yield in $T/y/km^2$				
	46	47	48	50	51
10th Percentile	0.0708	7.92	1.20	1.02	1.15
25th Percentile	**0.158**	**15.1**	**1.23**	**1.16**	**1.64**
50th Percentile	**0.351**	**20.3**	**1.28**	**1.80**	**2.35**
75th Percentile	**0.58**	**49.9**	**3.30**	**2.79**	**3.64**
90th Percentile	4.33	86.6	4.52	4.52	8.43
Number	13	19	3	19	12

UNSTABLE SITES					
	Mean annual suspended-sediment yield in $T/y/km^2$				
	46	47	48	50	51
10th Percentile	0.226	12.1	3.56	8.73	4.05
25th Percentile	**0.788**	**37.2**	**4.75**	**11.9**	**4.66**
50th Percentile	**5.19**	**243**	**8.16**	**17.3**	**4.97**
75th Percentile	**7.87**	**568**	**11.2**	**48.4**	**6.11**
90th Percentile	10.2	650	16.9	67.2	13.3
Number	11	23	9	3	6

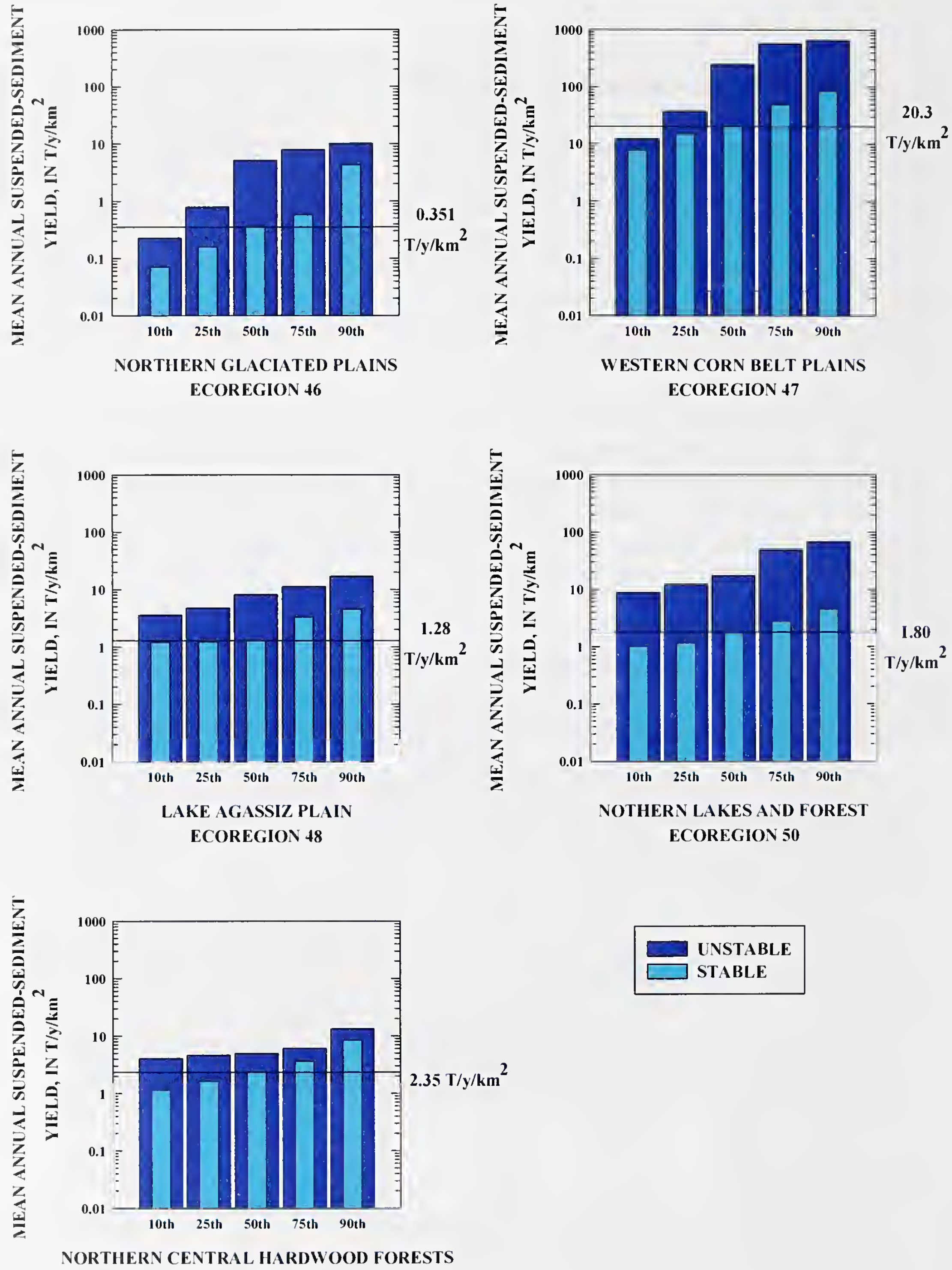


Figure 21 – "Reference" mean annual suspended-sediment yield (horizontal lines) and quartile values for both stable (light blue) and unstable (dark blue) channels.

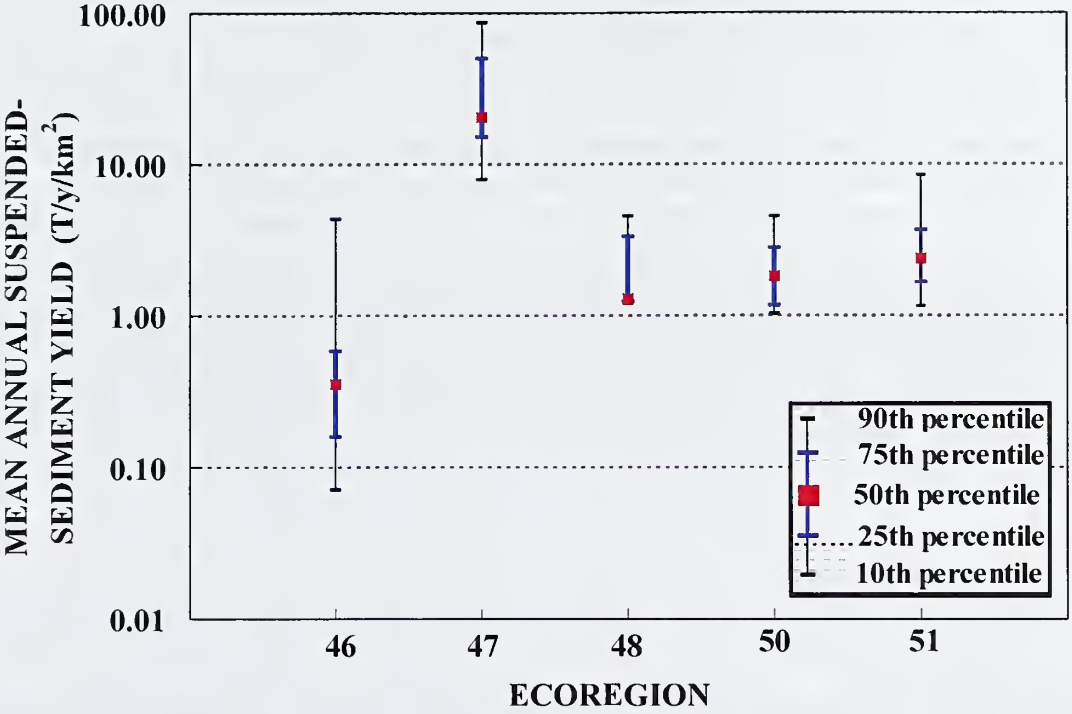


Figure 22 – Differences in "reference" mean annual suspended-sediment yield and quartile values between Level III Ecoregions in Minnesota. Ecoregion 48 10th, 25th and 50th percentile yield values vary just 0.08 T/y/km^2 and therefore markers for each value cannot be seen in the above graph.

To further test the validity of the approach of determining annual "reference" transport rates by differentiating between geomorphically stable and unstable channels, statistical tests to compare data distributions within each ecoregion were conducted. The t-test was used for normally-distributed data while the Mann-Whitney rank sum test was used to compare median values for non-normally distributed data. For each of the ecoregions studied, it was found that "reference" sediment yields were significantly different (p-value < 0.05) than sediment yields for unstable channels within the same Level III Ecoregion (Table 14).

Table 14 – Tests of statistically significant differences for mean annual suspended-sediment yields between stable and unstable channels in the studied Level III Ecoregions.

		Mean annual yields			
Level III Ecoregion	**Statistically significant difference between stable and unstable yield values**	**Normally distributed**	**Stable n**	**Unstable n**	**P value**
46	Yes	No	13	10	0.017
47	Yes	No	19	23	0.001
48	Yes	Yes	3	9	0.042
50	Yes	No	3	19	0.013
51	Yes	No	6	12	0.028

5.5 Suspended-Sediment Yields by Drainage Basin Size

To address concerns regarding the potential application of "reference" sediment-yield values for large fluvial systems, developed using data from a range of drainage basin sizes, an evaluation of data trends by basin size was conducted (Appendix D). By definition, suspended-sediment transport data expressed as yields accounts for differences in drainage area, as loads are divided by area to produce values in T/km^2. Still, there remains uncertainty as to whether values from basins of vastly different sizes can be compared because it is assumed that there is greater sediment storage (lower yields) in larger systems. To investigate this question, suspended-sediment yields were sorted into groups based on order-of-magnitude differences in watershed area (ie. 0 - 100, 101 – 1000 km^2 etc.) and are available in Appendix D.

As ecoregions are separated into several drainage-area categories, the number of data available within each category decreases dramatically, with most drainage basin size classes having between 3 and 5 sets of data available for calculation, with a maximum of 9 sites with yield data in the 100 – 1000 km^2 class of Ecoregion 50. As a result of such small sample sizes, any 'patterns' seen between drainage basin size classes should be used with caution. This being said, a small decrease in both mean annual and $Q_{1.5}$ "reference" suspended-sediment yield is noticed with increasing drainage basin size in Ecoregion 46. "Reference" suspended-sediment yield data is only available for two drainage basin size classes in each of the other Level III Ecoregions, therefore patterns cannot be established. Yield values for unstable sites are consistently greater than for stable sites, however, there are an insufficient number of sites within the range of drainage-basin size categories to interpret differences in the data.

5.6 Suspended-Sediment Transport Rating Equations

To investigate the possibility of developing "reference" sediment-transport relations for a given ecoregion, the initial, one-stage rating equations for each site were sorted again into stable and unstable groups. As these power functions are comprised of two parameters, a coefficient and exponent, quartile measures of these were calculated for each Level III Ecoregion (Table 15). The median and quartile values of each were then used to solve for suspended-sediment load over a range of discharges. Solved ratings are shown in Figure 23 for each Level III Ecoregion; solid lines represent the median, dashed lines represent the inter-quartile range. As expected, rating equations developed from median values for unstable sites generally result in order-of-magnitude higher loads than their respective "reference" ratings for stable sites, in most cases. Exceptions to this are Ecoregions 48 and 51, where these Ecoregion-wide ratings developed for the two types of channels cannot be differentiated from one another. In Ecoregion 48 this is probably due to a lack of "reference" sites and available data; calculations of a generalized rating are made with just five sites. Tests of statistical significance of differences were carried out on rating coefficients and exponents, the values of which are given in Table 16. Tests of statistical significance (p-values) of differences show a difference in either the coefficient or exponent between stable and unstable channels in Ecoregions 46 and 47 only (Table 16). However, the power of performed tests (0.05) were below the desired power (0.8),

in which case a lack of difference should not be over-interpreted as a difference may still exist. Low population numbers may be responsible for a lack of statistical significance in differences between stable and unstable channel rating equations in many ecoregions.

Table 15 – Rating equation quartile measure for all, stable and unstable sites for Level III Ecoregions of Minnesota. Equations take the general form of $y = a x^b$, where y = load in tonnes; x = discharge in m^3/s; a and b are coefficient and exponent values determined by regression.

ALL SITES	Ecoregion 46		Ecoregion 47		Ecoregion 48		Ecoregion 50		Ecoregion 51	
	Coefficient	Exponent	Coefficient	Exponent	Coefficient	Exponent	Coefficient	Exponent	Coefficient	Exponent
10th Percentile	1.37	0.905	0.360	1.25	0.471	1.19	0.0712	1.02	0.0840	0.952
25th Percentile	**2.19**	**0.958**	**0.935**	**1.41**	**0.943**	**1.27**	**0.123**	**1.21**	**0.211**	**1.20**
50th percentile	**3.51**	**1.07**	**3.96**	**1.70**	**2.05**	**1.43**	**0.275**	**1.56**	**0.669**	**1.36**
75th Percentile	**8.17**	**1.23**	**25.3**	**1.92**	**4.43**	**1.54**	**1.09**	**2.10**	**1.48**	**1.59**
90th Percentile	9.84	1.45	98.9	2.18	8.74	1.66	6.00	2.63	2.68	1.92
Number	38	38	63	63	14	14	69	69	52	52

STABLE SITES	Ecoregion 46		Ecoregion 47		Ecoregion 48		Ecoregion 50		Ecoregion 51	
10th Percentile	1.03	0.909	0.310	1.22	1.06	0.987	0.0630	1.04	0.0750	1.10
25th Percentile	**1.64**	**0.945**	**0.802**	**1.37**	**1.95**	**1.01**	**0.106**	**1.18**	**0.320**	**1.21**
50th percentile	**2.71**	**1.02**	**1.94**	**1.62**	**3.83**	**1.15**	**0.275**	**1.64**	**0.740**	**1.43**
75th Percentile	**4.67**	**1.16**	**3.94**	**1.79**	**4.64**	**1.35**	**0.820**	**2.20**	**1.77**	**1.67**
90th Percentile	9.28	1.24	7.67	1.89	4.99	1.47	8.80	2.60	5.77	1.99
Number	18	18	23	23	5	5	43	43	25	25

UNSTABLE SITES	Ecoregion 46		Ecoregion 47		Ecoregion 48		Ecoregion 50		Ecoregion 51	
10th Percentile	3.04	0.949	0.604	1.34	0.467	1.18	0.109	1.33	0.485	0.795
25th Percentile	**4.44**	**1.03**	**2.33**	**1.52**	**0.943**	**1.27**	**0.174**	**1.72**	**0.588**	**1.29**
50th percentile	**6.67**	**1.16**	**10.0**	**1.79**	**1.68**	**1.41**	**0.884**	**2.11**	**0.774**	**1.35**
75th Percentile	**9.34**	**1.34**	**60.6**	**2.01**	**4.47**	**1.57**	**2.38**	**2.43**	**2.29**	**1.47**
90th Percentile	11.9	1.46	132	2.16	46.0	1.72	5.75	2.77	3.6	1.96
Number	15	15	32	32	10	10	8	8	9	9

Table 16 – Statistical significance of differences between stable and unstable rating equations for Level III Ecoregions of Minnesota.

Level III Ecoregion	Coefficient: Statistical significance between stable and unstable	Coefficient: p-value	Exponent: Statistical significance between stable and unstable	Exponent: p-value	Stable n	Unstable n
46	Yes	0.01	Yes	0.045	20	14
47	Yes	0.002	No	0.115	23	32
48	No	0.958	No	0.474	5	12
50	No	0.415	No	0.320	8	43
51	No	0.532	No	0.468	9	25

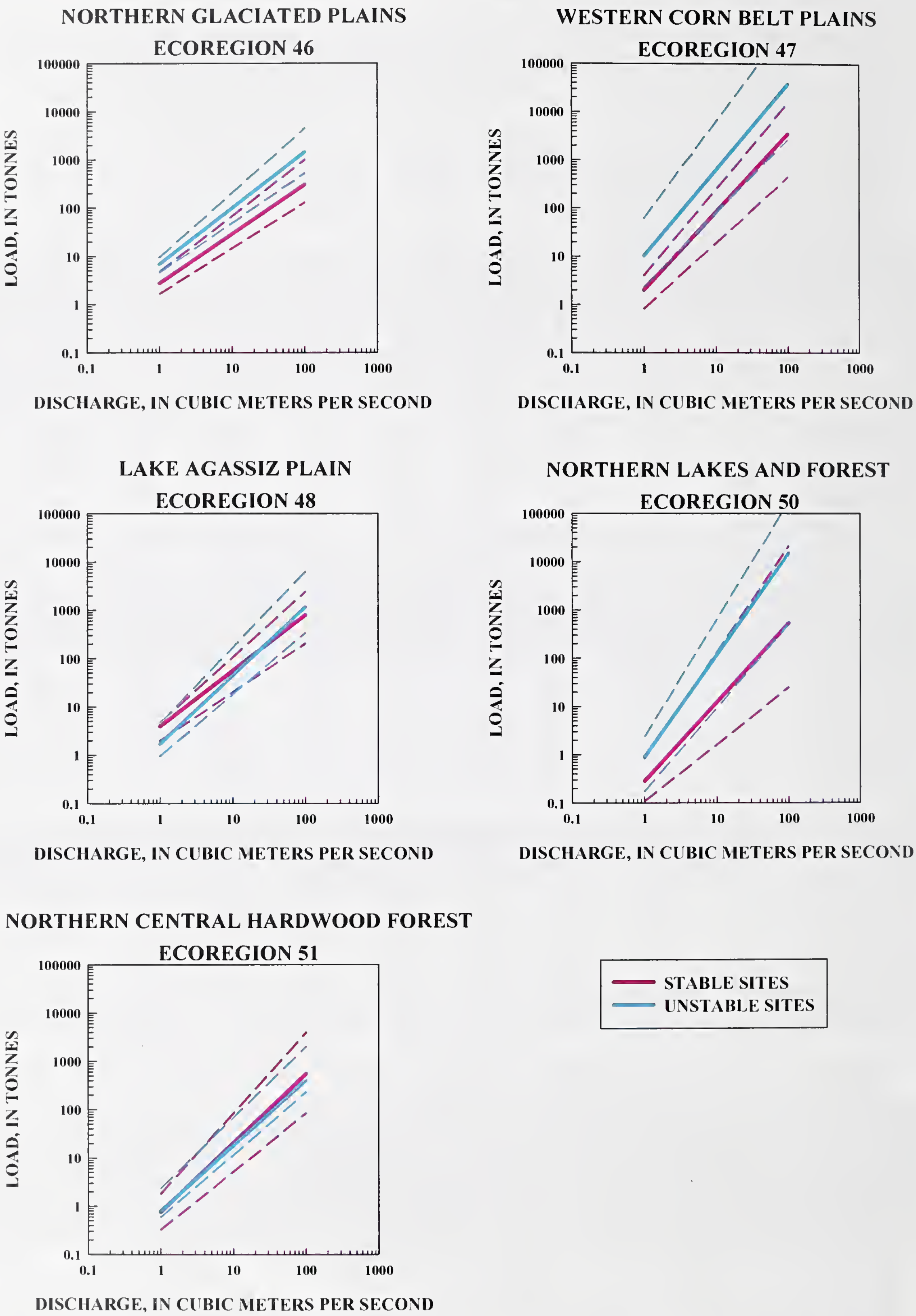


Figure 23 – Median (solid lines), 25th and 75th percentile (dashed lines) rating equations solved for stable and unstable channels over a range of discharges.

Median “reference” ratings are plotted for all Level III Ecoregions in Minnesota in Figure 24, providing an overview of differences in sediment-transport regimes in these ecoregions. The concept behind this was to attempt to develop a tool by which TMDL practitioners could estimate “reference” sediment-loads for ungaged watersheds.

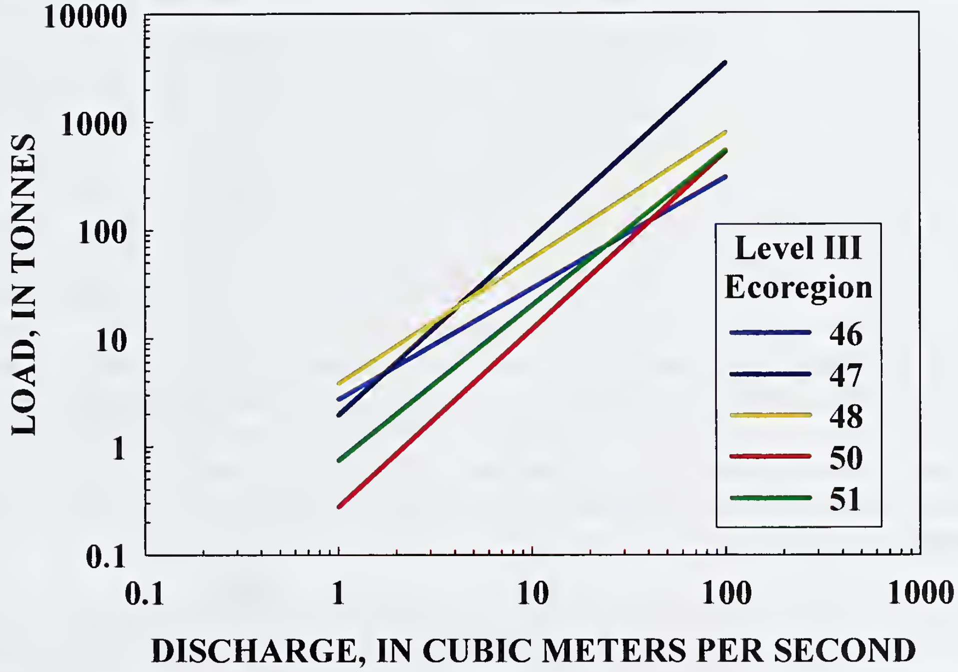


Figure 24 – “Reference” rating equations (median values for *stable* channels) solved for a range of discharge values to provide load estimates, in tonnes, for each ecoregion.

There is no clear ‘grouping’ of ecoregion rating equations in Figure 24. Ecoregions 47 and 50 have the steepest gradients, therefore channels in these ecoregions transport much higher levels of suspended-sediment proportionally during storm events, than other ecoregions of Minnesota. At low and moderate flows, much of the suspended sediment emanates from the channel boundary. Almost 60 % of Ecoregion 50 “reference” channels were dominated by more resistant coarse-grained bed material, potentially accounting for the lowest coefficient values in Minnesota. The rating equation for Ecoregion 46 has the lowest gradient of the five ecoregions, yet the second highest coefficient. This suggests that channels in this ecoregion transport relatively high volumes of suspended-sediment even during low flow situations, but storm response is less severe than in other areas. In comparison to the other sixteen Level III Ecoregions across the U.S. for which these calculations have been made, a median “reference” coefficient of 2.71 for Ecoregion 46 is relatively high; only exceeded by Ecoregions 43, 48, and 74 with median “reference” coefficient values of 5.97, 3.83 and 2.79 respectively (Simon *et al.*, 2008, Klimetz and Simon 2006). This reasonably high coefficient value may be a result of flatter gradients and finer boundary sediments that characterize channels in Ecoregion 46, where low flows are still able to entrain and transport sediment. At the highest flows, stable channels from each of the ecoregions transport similar loads, with the exception of Ecoregion 47 which has a reasonably high coefficient and exponent, resulting in particularly high suspend-sediment loads during high flow situations.

5.7 Suspended-Sediment Concentrations

5.7.1 Frequency-Magnitude of Suspended-Sediment Concentration

Suspended-sediment yields, either at the $Q_{1.5}$ or representing mean-annual values have been used thus far to develop "reference" sediment-transport rates. In this section, the data were re-cast in terms of the frequency and duration that specific concentrations of suspended-sediment can be expected. It was hoped that by expressing the data this way that it would be potentially useful for developing sediment-transport metrics that could ultimately be related to biological functions and thus issues of surface water 'designated uses'. As one would expect, median suspended-sediment concentrations (in milligrams per liter) were lower in stable or "reference" channels at a given percent exceedance than in unstable channels in most Level III Ecoregions (solid lines in Figure 25). Exceptions to this can be seen at lower suspended-sediment concentrations in Ecoregions 47, 48 and 51, where stable channels are calculated to transport equal or higher concentrations of suspended-sediment than unstable channels. Differences between the frequency of occurrence for stable and unstable streams appear more important (significant) at moderate and high flows, suggested by the greatest differences in 99.99 percentile concentrations (concentrations exceeded just 0.01 % of the time).

Problems with the frequency-duration data for Ecoregion 48 exist because data sets from only five stable sites were used to develop the magnitude-frequency relation (Figure 25). In addition, rating relations for stable sites that were used in the calculations were developed from mean-daily discharge data, not the instantaneous flow data (from discharge measurements) that was employed for other sites (L. Tornes, U.S. Geological Survey, written comm., 2007).

Inter-quartile ranges are quite broad within each ecoregion (shown as the dashed lines in Figure 25); however this may be a function of the quantity of data available in each ecoregion, rather than the data values themselves. Channel size and range of concentrations of suspended-sediment transport vary greatly both within and between ecoregions. There is no overlap of inter-quartile ranges between stable and unstable channels in Ecoregion 50, and only a slight overlap in concentrations exceeded just 0.1 % of the time in Ecoregion 46. Therefore, unstable channels consistently transport higher concentrations of suspended-sediment than stable channels in the both the Northern Glaciated Plains and the Northern Lakes and Forests.

There are many ephemeral streams within the dataset of Ecoregions 46 and 48 (The Northern Glaciated Plains and the Lake Agassiz Plains respectively). This greatly affects frequency-magnitude calculations and further calculations with this data such as magnitude-duration and dosage, as zero concentrations are sustained for extended periods of time.

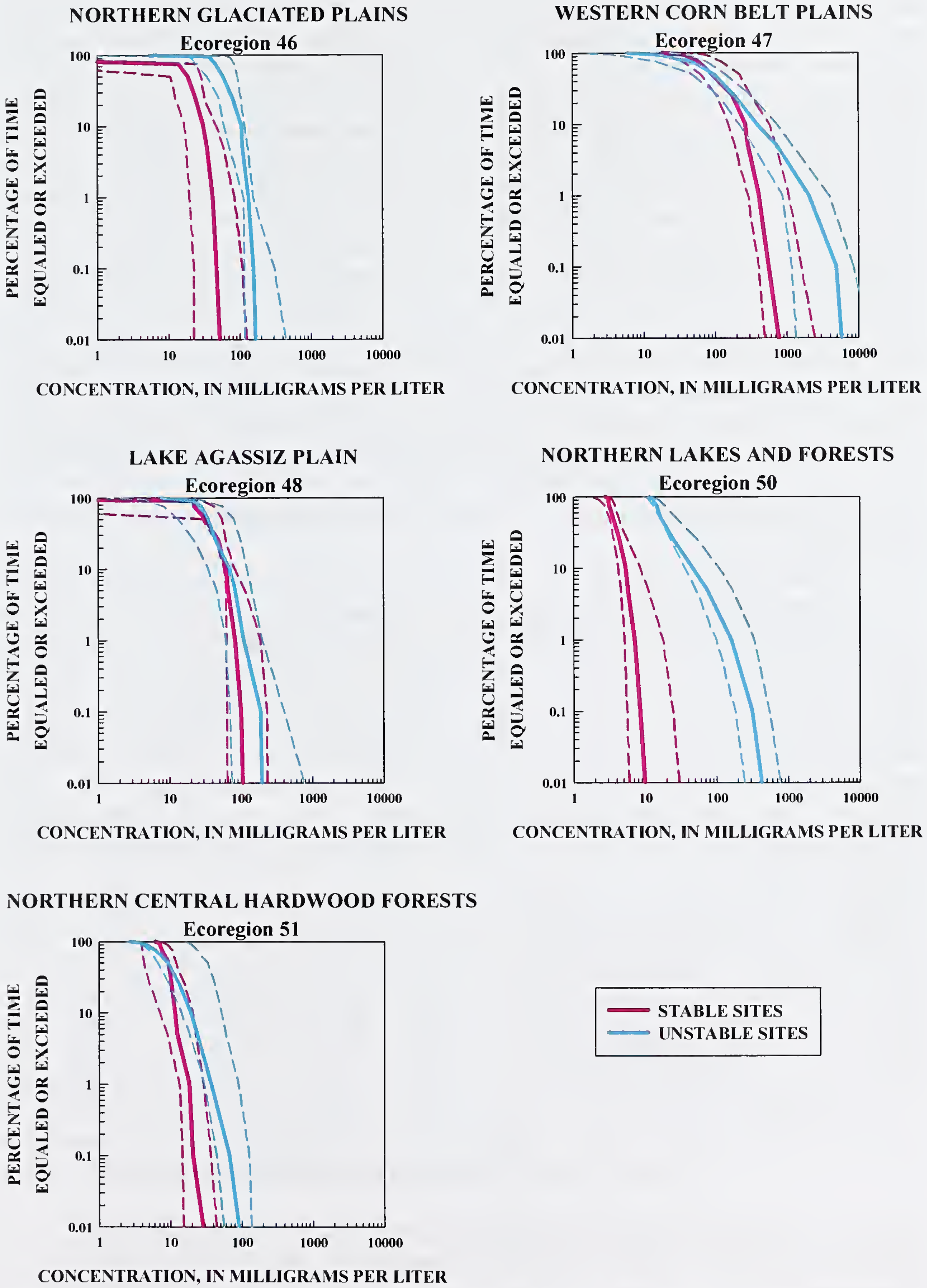


Figure 25 – Inter-quartile (dashed) and median (solid) measures of concentration frequency-magnitude for Level III Ecoregions of Minnesota. Pink lines represent stable or "reference" channels, blue lines represent unstable channels.

Differences between median "reference" concentration frequency-magnitude relations for the Level III Ecoregions of Minnesota are given in Figure 26. There are no apparent groupings between ecoregions when considering median frequency-magnitude "reference" values. Ecoregion 50 stands out as having not only the lowest storm-event (low frequency, exceeded just 0.01 % of the time) concentration of 9.9 mg/l, it also has the smallest range in concentrations between those exceeded 100 % of the time and just 0.01 % of the time (7.1 mg/l), in contrast to Ecoregion 47 with the highest low frequency concentration of 767 mg/l and the highest range in concentrations (748 mg/l). The Northern Lakes and Forest (Ecoregion 50) encompasses an area of both deciduous and evergreen forest in which vegetation remains year round, and is abundant with lakes and undulating plains. Returning to earlier discussions regarding dominant bed material and entrainment into the water column (Section 5.6), almost 60 % of stable channels visited in Ecoregion 50 were dominated by a coarse-grained bed material, providing little fine material for suspension. In contrast to this, land-use in the Western Corn Belt Plains (Ecoregion 47) is predominantly agriculture, therefore likely undergoing regular periods of low vegetation cover following the harvest and 90 % of the stable channels were dominated by a fine-grained bed material, entrained into suspension at even the lowest of flows; stable sites transport 18 mg/l 99 % of the time, compared to just 2.8 mg/l in Ecoregion 50.

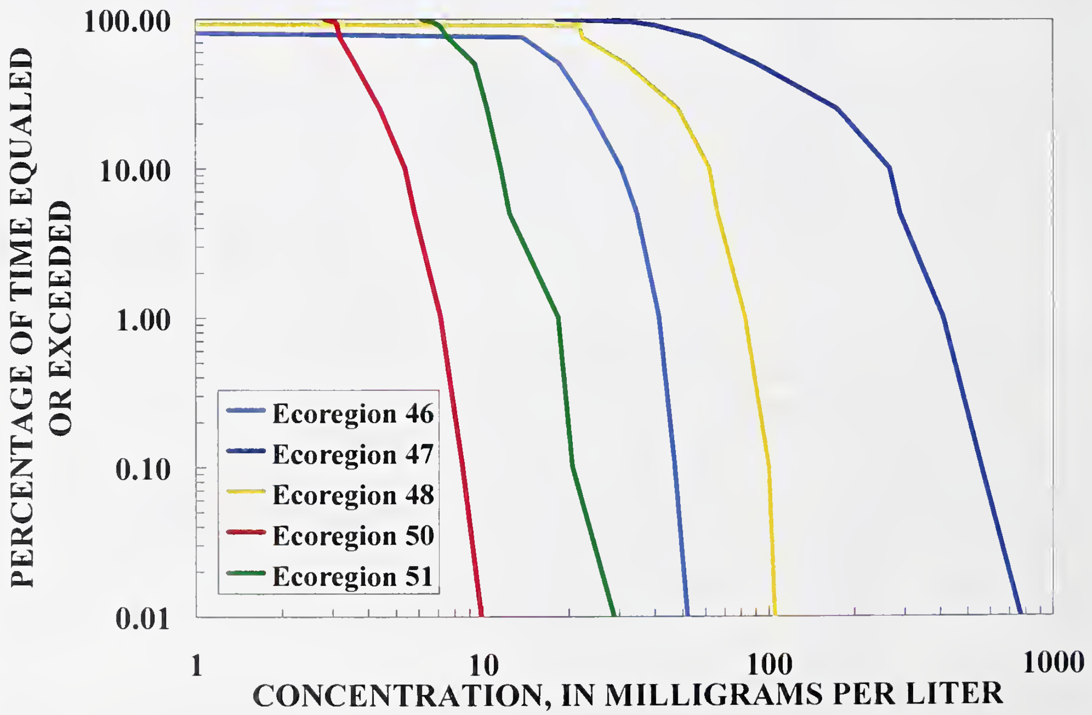


Figure 26 – Median values representing the percentage of time concentration is equaled or exceeded in *stable*, "reference" channels for Level III Ecoregions in Minnesota.

5.7.2 Magnitude-Duration of Suspended-Sediment Concentration

Differences in concentration values between stable and unstable channels evident in the frequency-magnitude plots for the Level III Ecoregions (Figure 25, above), are somewhat skewed and amplified in plots of duration-magnitude (Figure 27). One of the reasons for this is that the duration data are continuous, expressed as the number of consecutive days a given concentration is equaled or exceeded, causing sharper breaks in the distributions. The separation between stable and unstable inter-quartile frequency-magnitude-duration concentration ranges is much less obvious than when simply considering magnitudes of concentration events. In fact the only clear separation between stable and unstable concentrations occurs in the Northern Lakes and Forests, Ecoregion 50. It is important to consider data quality when examining magnitude-duration plots as mean-daily discharge data is used to calculate sediment concentration durations and any break in this continuous dataset, such as equipment malfunction or ice cover, will appear as a 'break' in continuous flow where none such change in discharge occurred.

Unstable sites transport higher concentrations of suspended-sediment for any given duration in Ecoregions 46, 48 and 50, however in all but the latter Ecoregion, inter-quartile ranges overlap. Across the entire range of durations, stable channels were calculated to transport higher concentrations of suspended-sediment than unstable channels in Ecoregion 47, and during events lasting less than 20 consecutive days in Ecoregion 51. RGAs carried out in Ecoregion 47 determined stable channels to have relatively high indices of channel stability compared to other parts of the country; possibly a combination of a general lack of bank vegetation, protection on some banks causing flow deflection to opposite banks and the presence of fluvial erosion at some sites. The sites determined to be stable in Ecoregion 47 therefore may have recently become stable channels with an abundance of suspended-sediment from areas which remain unstable upstream. Other than Ecoregion 47, stable and unstable concentrations diverge into the expected pattern of higher concentrations in unstable channels for the shorter duration, more extreme events. The durations of specific concentrations are almost always greater for the unstable channels in all of the ecoregions (with Ecoregion 47 being the only exception), lending further support to the idea of using these types of data to investigate differences in biological distribution and function. It should be noted that not only do unstable channels transport greater amounts of sediment per unit area (yields), and do so at greater frequency, but also maintain high concentrations for longer durations than in stable, "reference" streams. This is a key element in calculations of dosage, which will be discussed in a later section of this report. There is, however, uncertainty in differentiating between stable and unstable trends as indicated by the spread of the inter-quartile ranges (Figure 27).

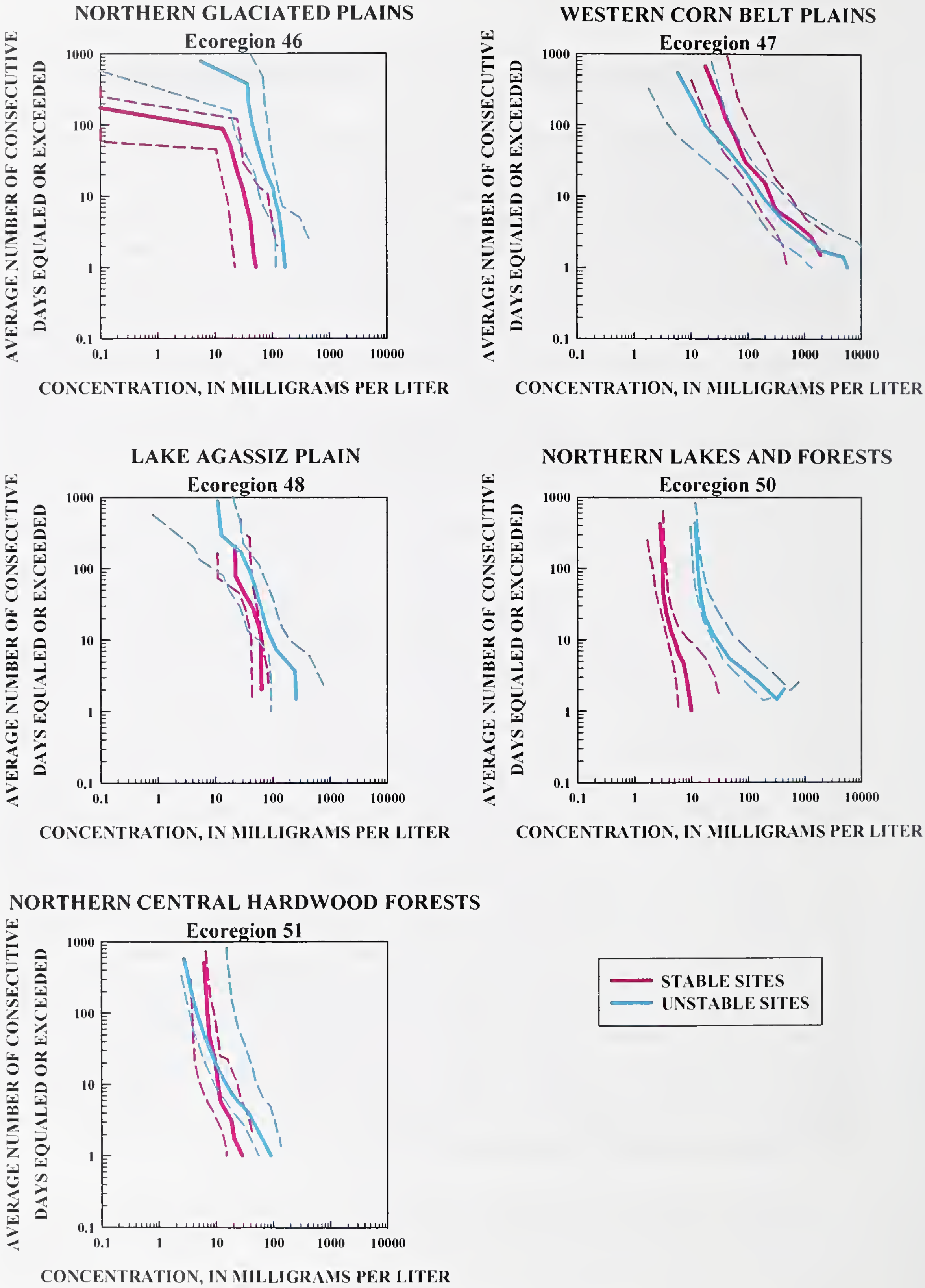


Figure 27 – Inter-quartile (dashed) and median (solid) measures of concentration frequency-magnitude-duration for Level III Ecoregions in Minnesota.

Patterns between Level III Ecoregions (Figure 28) follow the same pattern as the frequency-magnitude plot (Figure 26). The existence of many ephemeral streams in Ecoregions 46 and 48 result in many zero-discharge days, therefore there is no concentration information below 14 and 22 mg/l in these ecoregions. The spread of suspended-sediment concentrations that median stable channels within a given Ecoregion can transport is immense, increasing as concentration event durations decrease. For example concentrations of approximately 3.1 mg/l and 49 mg/l are exceeded for an average of 100 days in Ecoregions 50 and 47 respectively; the difference between these two ecoregions at either end of the spectrum increases when an event lasting just 10 days is considered, when concentrations are 5 and 250 mg/l, respectively.

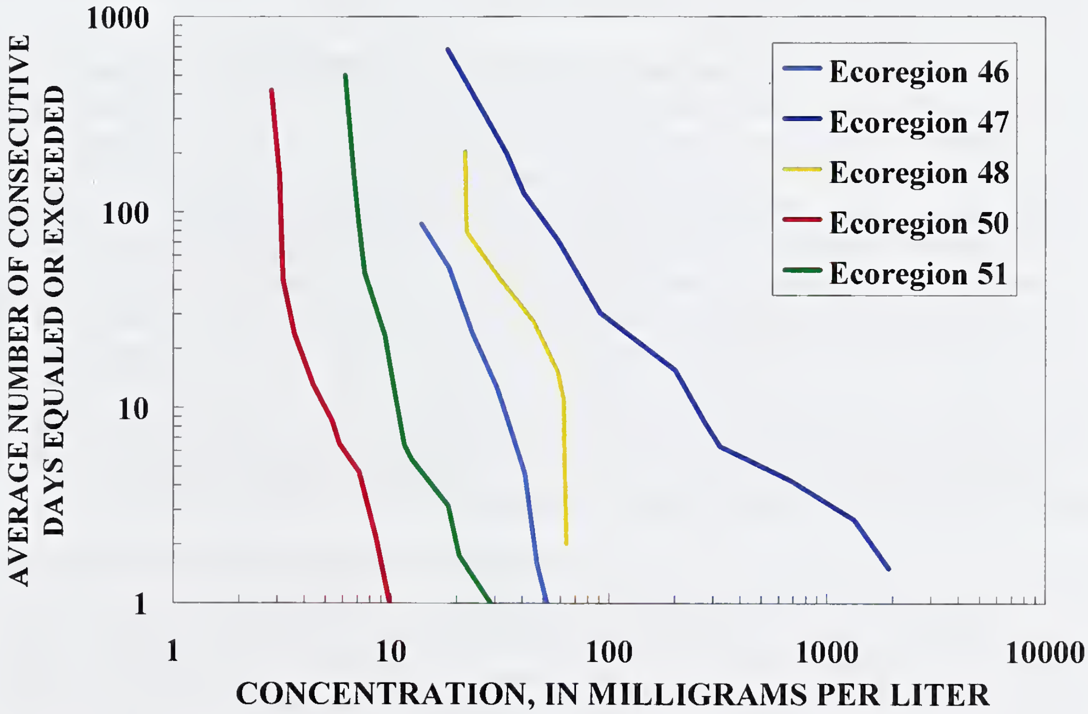


Figure 28 – Median values for the average number of consecutive days a given concentration is equaled or exceeded in *stable*, "reference" channels for Level III Ecoregions of Minnesota.

5.7.3 Suspended-Sediment Concentration Dosage and Dosage Impact

'Dosage' may be an important parameter in studies of the impact of a given pollutant on aquatic biota. In the case of suspended-sediment, dosage is calculated as the product of the suspended-sediment concentration and the continuous duration (in number of consecutive days) and would, therefore be expressed in mg-days per liter (mg-d/l). Quartile values for dosage within a specific ecoregion were calculated from data for each site and sorted into stable and unstable sites within the ecoregion. Maximum dosage values in each ecoregion should be indicative of the concentration and associated flow(s) that has the greatest potential to impact biological communities. This may be masked to some extent by the effects of using an arithmetic distribution of exceedance classes, which often results in the maximum value being in the lowest concentration class (ie. concentration exceeded 100% of the time) (Simon *et al.*, 2004a).

Data for all Minnesota Ecoregions are displayed in Figure 29 and show distinct differences between median values for stable and unstable sites across the plotted range of concentration exceedances in most all cases. Exceptions to this occur during low frequency concentration events, or those equaled or exceeded more than 10 % of the time in Ecoregion 47, more than 50 % of the time in Ecoregion 48 and between 90 and 99 % of the time in Ecoregion 51. Stable and unstable channels appear to transport similar suspended-sediment dosages during the infrequent, short-duration, high flow events. All graphs in Figure 29 have the same axes range so that comparisons can be made between ecoregions, and stable median dose values are plotted in Figure 30. Particularly low and high dosage values are estimated and given by gray lines for Ecoregion 46, again as a result of ephemeral streams which have zero-dosage values. Ecoregion 47 has the highest dosage values, in terms of both stable and unstable channels, while Ecoregion 50 has the lowest, and the clearest separation between stable and unstable channels.

These order-of magnitude differences in "reference" sediment dosage between some ecoregions may explain differences in biological communities between those ecoregions. This statement is merely supposition at this point because matching biological data is either not available or is beyond the analytic scope of this project. If we further consider the question of which flows and associated concentrations and dosages are most effective in controlling biological functions, we could focus on the peak dosage value within each ecoregion as a potential metric. This may allow us to obtain insight into the question of which flow(s) and associated sediment dosage plays the most crucial role in biological community distribution, stress and impact; the highest concentrations that occur over very short durations, or a moderate concentration that occurs over prolonged periods. Considering the cautionary note provided above, regarding peak values found in the lowest concentration class, we look to the secondary peak of the distribution if the peak is located in the lowest concentration class (100% exceedance).

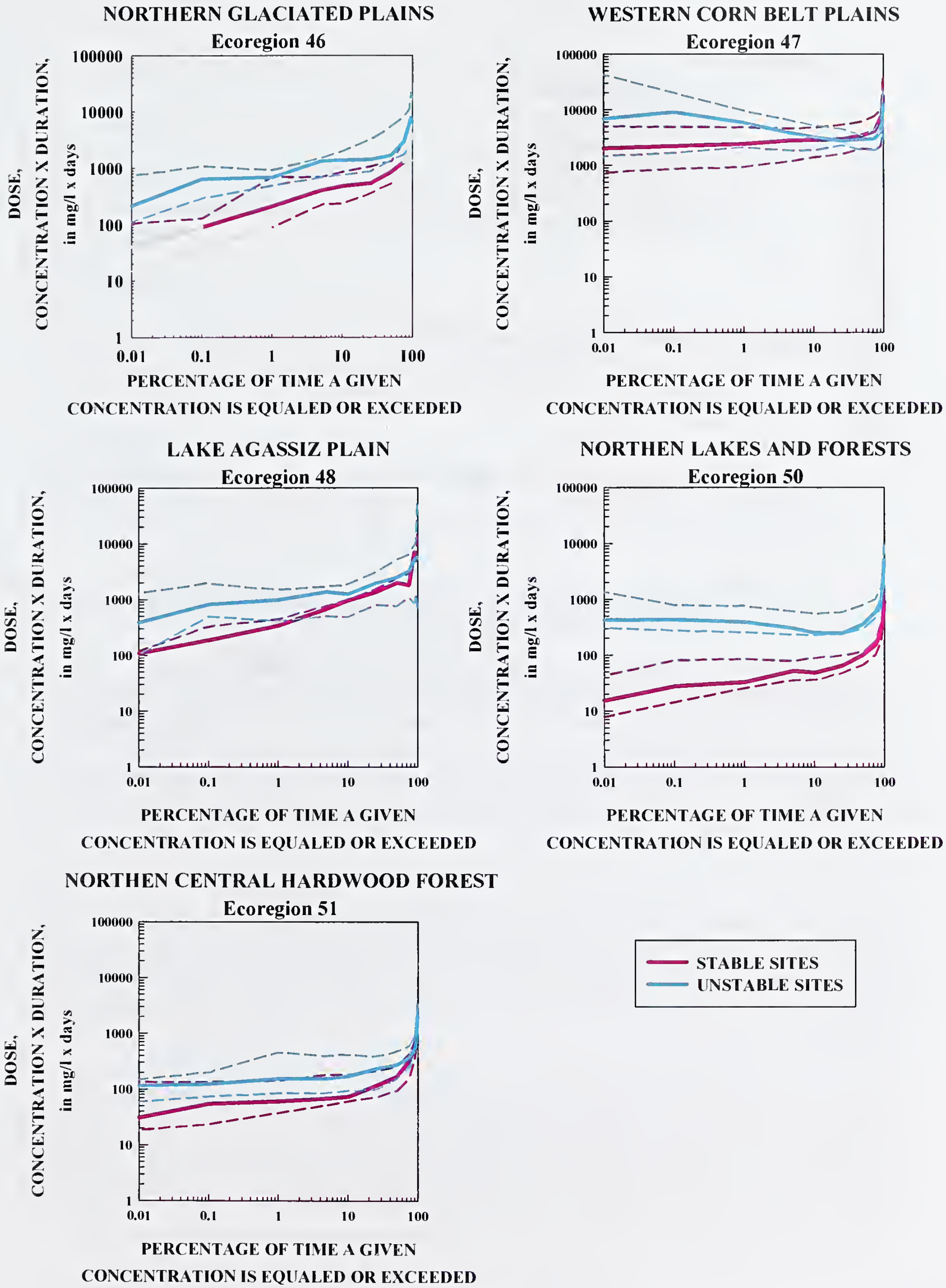


Figure 29 – Inter-quartile (dashed) and median (solid) measures of suspended-sediment dosage (concentration x duration) for stable (pink) and unstable (blue) sites in Minnesota. Gray lines in Ecoregion 46 represent estimated dosage values due to the number of ephemeral channels in this ecoregion.

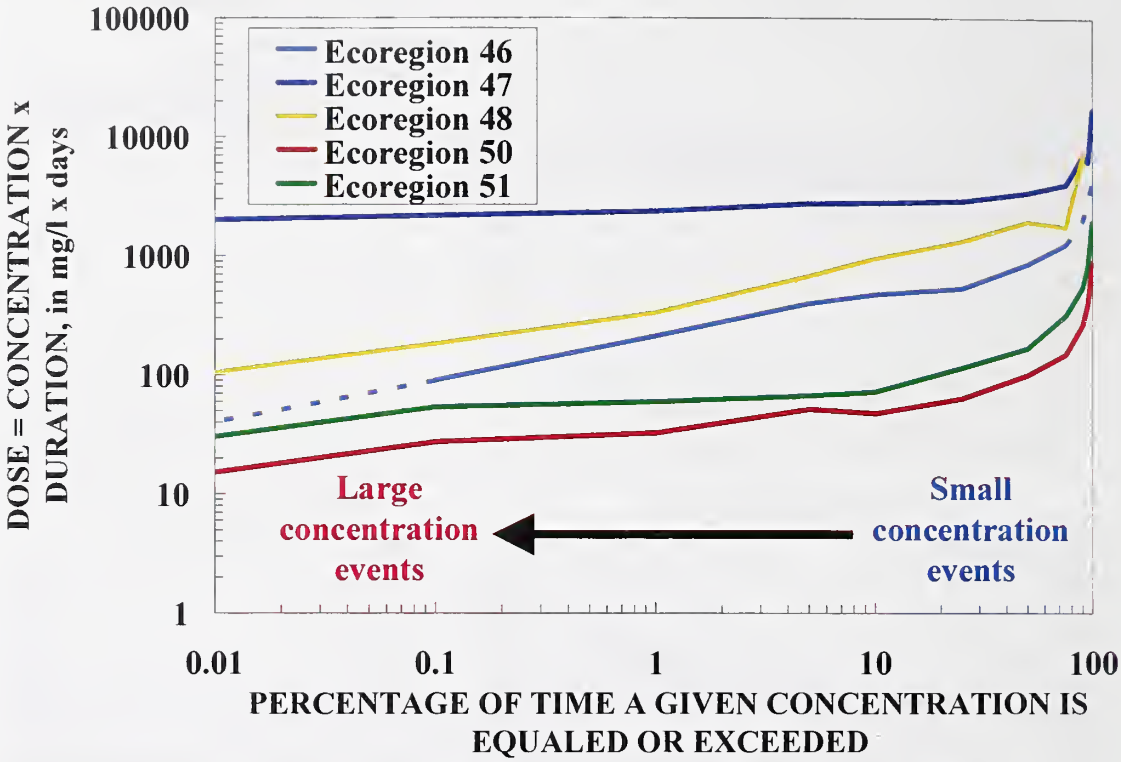


Figure 30 – Distribution of median suspended-sediment dosage over a range of concentration exceedance values in *stable* channels for Level III Ecoregions in Minnesota. The dashed blue line represents estimated values for Ecoregion 46, as dosage cannot be calculated at concentrations less than 13 mg/l due to the number of ephemeral channels in the Ecoregion regularly experiencing zero flow days.

"Reference" suspended-sediment dosage peaks at concentrations frequently exceeded, greater than 99 % of the time, therefore low concentration events. The only exception to this is Ecoregion 46, where data are skewed by ephemeral streams. This implies that low frequency, high concentration events may have a greater affect on sediment-sensitive organisms.

The metric, 'dosage impact' represents the difference in sediment dosage for stable and unstable conditions at a given concentration exceedance. A plot of these data using concentration exceedance on the abscissa provides a graphical portrayal of the magnitude and distribution of potentially adverse sediment-dosage effects. We see again that the distributions are largely skewed to the lowest concentration class (highest exceedance) but this is most likely the result of the use of arithmetic-class boundaries (Figure 31).

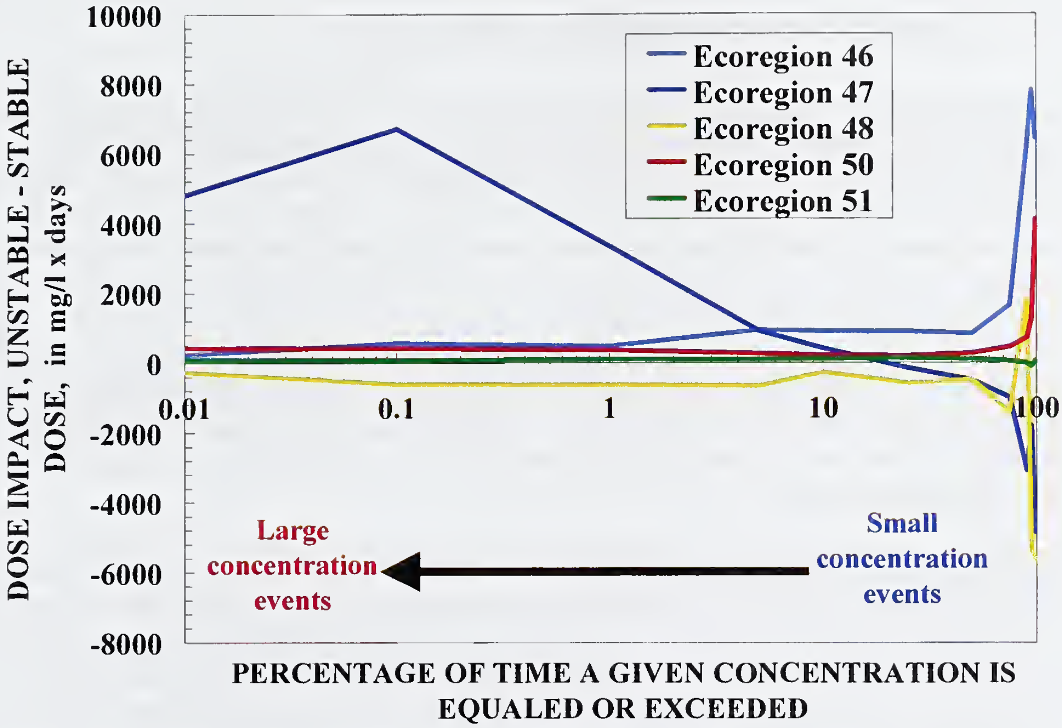


Figure 31 – Suspended-sediment dose impact (median unstable – median stable dose) for the Level III Ecoregions of Minnesota over a range of concentration-exceedance values.

Data are difficult to interpret for dosage impact and cannot be plotted on a logarithmic axes due to apparently negative impacts in Ecoregions 47, 48 and 51 (Figure 31). The greatest sediment dose-impacts occur during low-frequency high-magnitude concentration events in Ecoregion 47, but high-frequency low-magnitude concentration events in all other Ecoregions in Minnesota, whether impacts are positive (as in Ecoregions 46and 50) or negative (Ecoregions 48 and 51). This suggests that impairment of biologic communities due to sediment dosage may occur not only at the high flow-concentration events, but may also be linked to the generally higher concentrations that persist over long periods of time at moderate flows. The peak in dosage impact at concentrations occurring 0.1 % of the time in Ecoregion 47 (representing low-frequency high concentration events), is probably due to the increased contribution from channels sources, particularly streambanks, which become activated at higher flows. High-frequency events also yield a significant dosage impact in Ecoregion 47 suggesting that sediment concentrations and durations at moderate flows may also be of concern in this Ecoregion, however the impact is negative at these low-magnitude concentration events.

5.8 Trends in Precipitation and Flow: 1900 - Present

Temporal trends in average-annual precipitation and stream runoff were examined for each of the ecoregions included in the study. The purpose of this analysis was to investigate decadal-level variations in runoff as this variable is inherently related to sediment loadings (concentration times discharge). Runoff data were unitized by dividing by drainage area (in km^2) so that basins of different size could be included in the analysis. Data were then expressed as a water yield (in $m^3/s/km^2$). Changes in water yield over the last century may reflect alterations to the landscape (land use), direct modifications to stream channels (ie. channelization, dams), irrigation and changes in precipitation. An attempt was made to incorporate changes in precipitation into the interpretation of changes in runoff or water yield over the past century. The data used in this section only cover a 100-year period and, therefore, are not meant to make inferences about the broader issue of global climate change.

Precipitation trends over the past 100 years are shown in Figure 32 for each of the studied ecoregions; graph axes are constant to enable comparisons between Level III Ecoregions. The Dust Bowl era clearly stands out as below average precipitation between the mid to late 1920's and the late 1930's. Ecoregion 47 average-annual precipitation values are very erratic, ranging 616 mm (from 533 mm during the lowest precipitation year in 1976, to 1149 mm during the highest year in 1868) between 1867 and 2006. The other ecoregions have annual precipitation ranges of between 300 and 450 mm over the same time period. The 1990's was a wetter than average decade for all of the studied ecoregions, with a more recent 'dip' in precipitation in all ecoregions (there were no precipitation gages with a complete year of data during 2002 in Ecoregion 48, therefore the 5-year moving average ends at 1999). All of the ecoregions studied show an overall increase in precipitation values over the past century except for Ecoregion 47 which shows an average 0.129 mm/y decrease in precipitation (Figure 32).

Trends in water yield over the past century are shown in Figure 33. When comparing the median annual mean-daily water yield values for the period of record, the Ecoregions tend to group together. Ecoregion 46 has the lowest median annual mean-daily water yield of 0.00034 $m^3/s/km^2$, Ecoregions 47 and 48 group in the middle (0.0029 and 0.00183 $m^3/s/km^2$ respectively), with Ecoregions 50 and 51 having the greatest median annual water yields of 0.0098 and 0.0067 $m^3/s/km^2$. The response in water yield values to the drought of the Dust Bowl period is noticeable during the 1920's and 1930's in Ecoregions 50 and 51. For Ecoregions 46, 47 and 48, this period of was shifted to the 1930's and 1940's. These differences between trends in precipitation and water yield are probably the result of human influences and disturbances. Below average water yields continued until the early 1980's for Ecoregion 47, mirroring generally below average or average precipitation rates over the same time period. Over the period of record, all of the studied ecoregions of Minnesota show an increase in water yield; therefore an increase in runoff per unit drainage area (Figure 33). All ecoregions also show greater than average runoff during the 1990's, consistent with the period of high precipitation during this time.

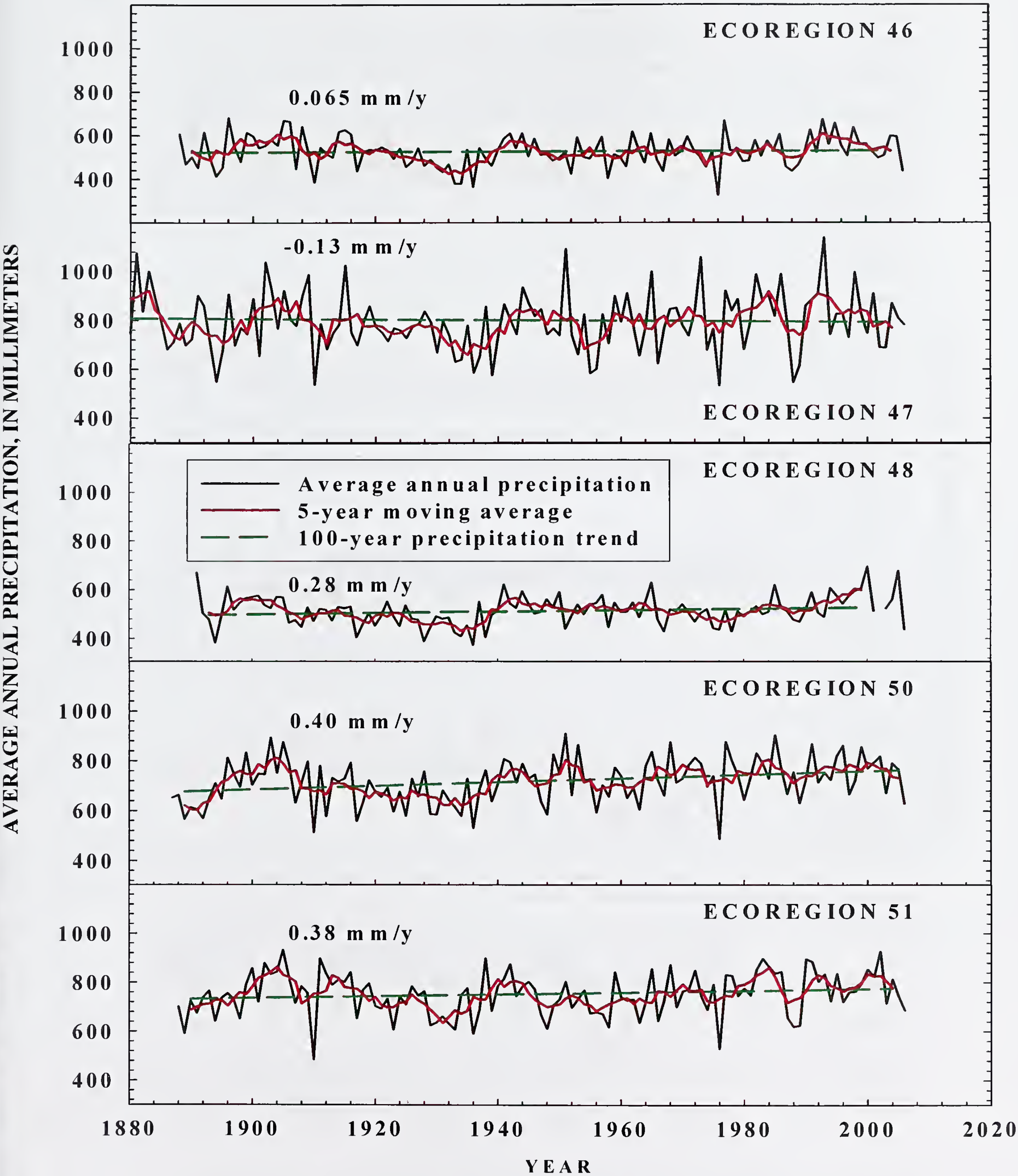


Figure 32 – Trends of average-annual precipitation for the studied ecoregions of Minnesota. The red line is a 5-year moving average and the green-dashed line represents the 100-year trend (also shown is the average annual change in mm/y).

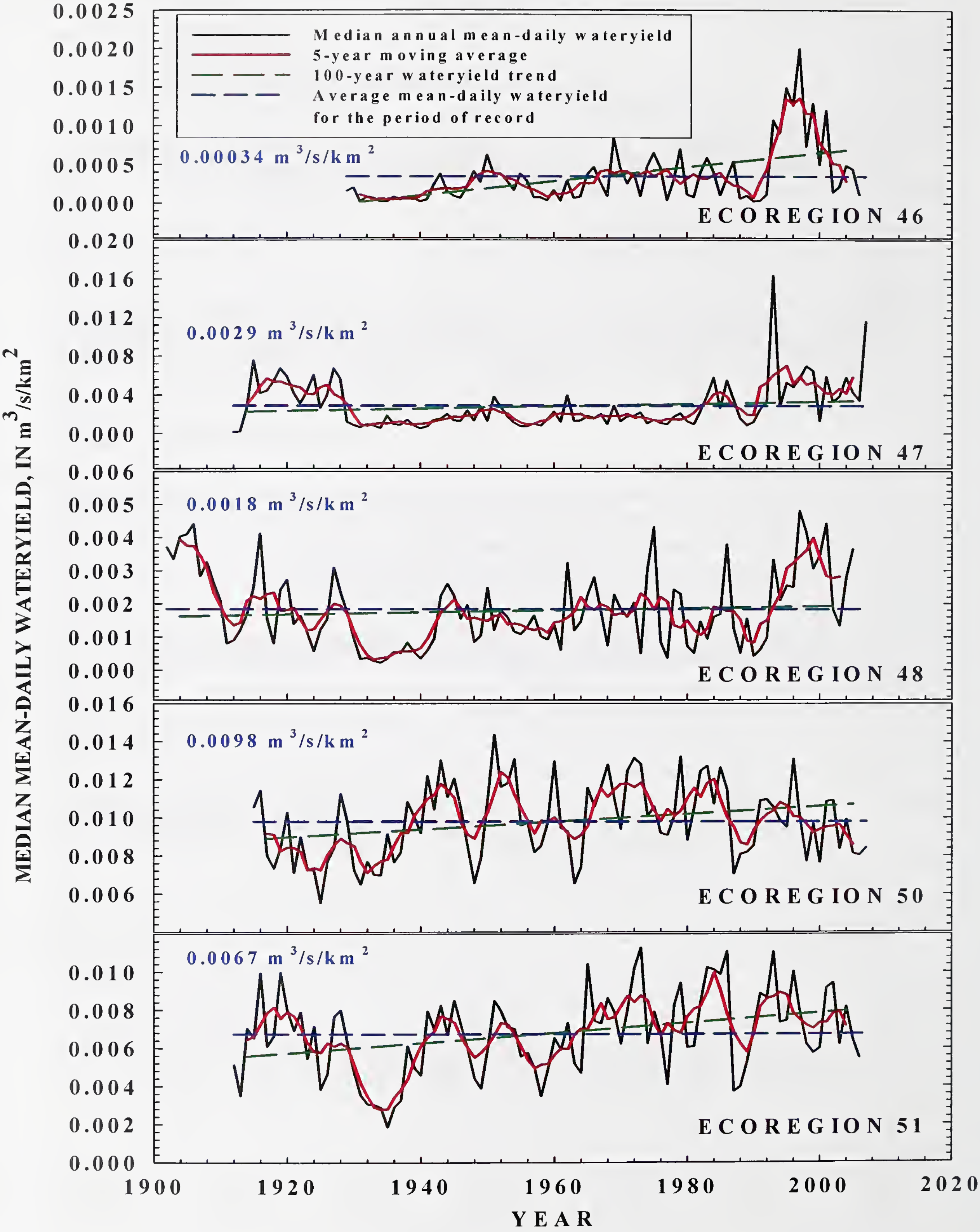


Figure 33 – Trends of average annual mean-daily water yield for the studied ecoregions of Minnesota. The red line is a 5-year moving average; the blue dashed line the mean values for all stations over the period of record, and the green dashed line the trend for the period of record.

Over the period of record, all of the studied ecoregions of Minnesota show an increase in water yield; therefore an increase in runoff per unit drainage area (Figures 33). All ecoregions also show greater than average water yield, or runoff, during the 1990's, consistent with the period of high precipitation during this time. Both precipitation and water yield data are expressed as a percent difference from the mean for the period of record in Figure 34. Patterns in water yield appear to parallel those found in precipitation for the most part in Ecoregions 48, 50 and 51; periods of below average precipitation coincide with periods of below average water yield, and vice versa. There are some instances in Ecoregions 46 and 47 where precipitation and water yield values do not seem to reflect one another. An example of this occurs during the 1940's in Ecoregion 46, when precipitation is approximately 8 % higher than average but water yield is around 50 % below average. As this period of higher precipitation follows twenty years of severe drought, there may be a re-charge situation in which reduced groundwater storage is replenished before significant in-channel contributions are made. It should however be noted that water yield data for Ecoregion 46 exists for a much shorter period than for other regions, with discharge data only available from 1929 in Ecoregion 46, therefore beginning the dataset during the Dust Bowl period, but being available from 1902 in Ecoregion 48, and the mid-1910's in the other Ecoregions.

There appear to be no recent area wide patterns in precipitation and water yield differences from mean values. Recent decreases in both precipitation and water yield are found in Ecoregions 46 and 48, however these remain above average. There has been a recent increase in already above average water yield in Ecoregion 47. Five-year averages of difference from mean-daily water yield mean value for the period of record are provided, in percent, for all ecoregions in Figure 35. It can be seen from Figure 35 that variability in water yield from the mean for the period of record is smallest in Ecoregions 50 and 51, a maximum difference of 50 and 75 % from the mean, respectively, compared to over 300 % difference from the mean in Ecoregion 46 during the 1990's. The large peaks between the mid 1990's and into this century in Ecoregions 46 and 48, where the 5-year moving average peaks at about 100 - 300 % above the long-term average, are related to large precipitation events and flooding on the Red River during this period. This minimal fluctuation in Ecoregion 50 and 51 water yield percent differences may be a function of the vast number of lakes and wetlands found in these ecoregions providing storage and therefore reducing in-channel water yield fluctuations. Minnesota itself has almost 148,000 km of rivers and streams and over 13,300 km^2 of lakes, ponds and reservoirs (EPA, 2004b). The large variations in percent difference from the mean water yield value for the period of record in Ecoregions 46, 47 and 48 may be a result of greater human influence in these ecoregions, than in the largely forested and wetland areas of Ecoregions 50 and 51; particularly Ecoregion 47 in which over 75 % of the land use cover is cropland agriculture and is "one of the most productive areas of corn and soybeans in the world" (EPA, 2002).

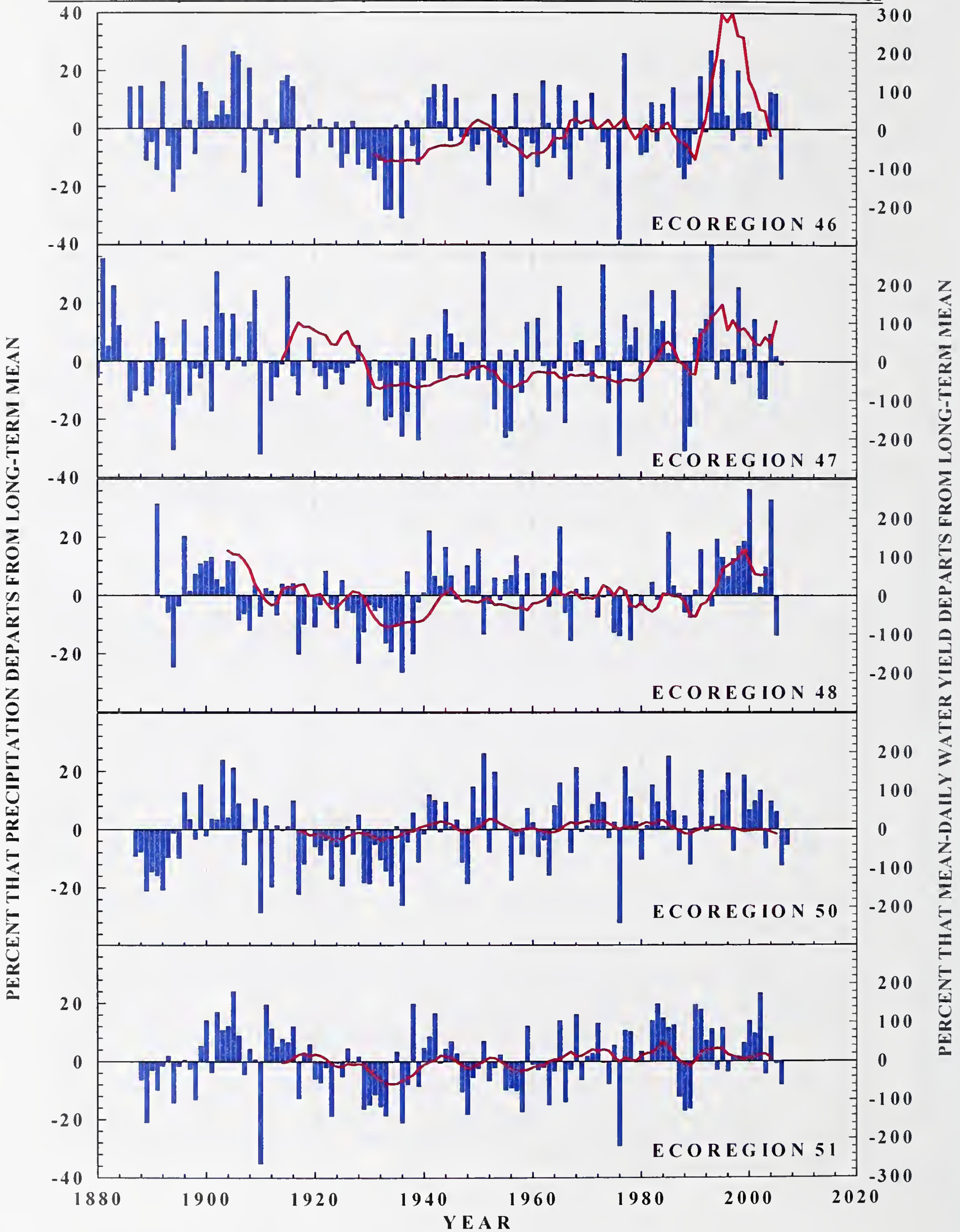


Figure 34 – Percent difference in average annual precipitation (blue bars) and the 5-year moving average for water yield (red line) from the period of record mean for each ecoregion studied.

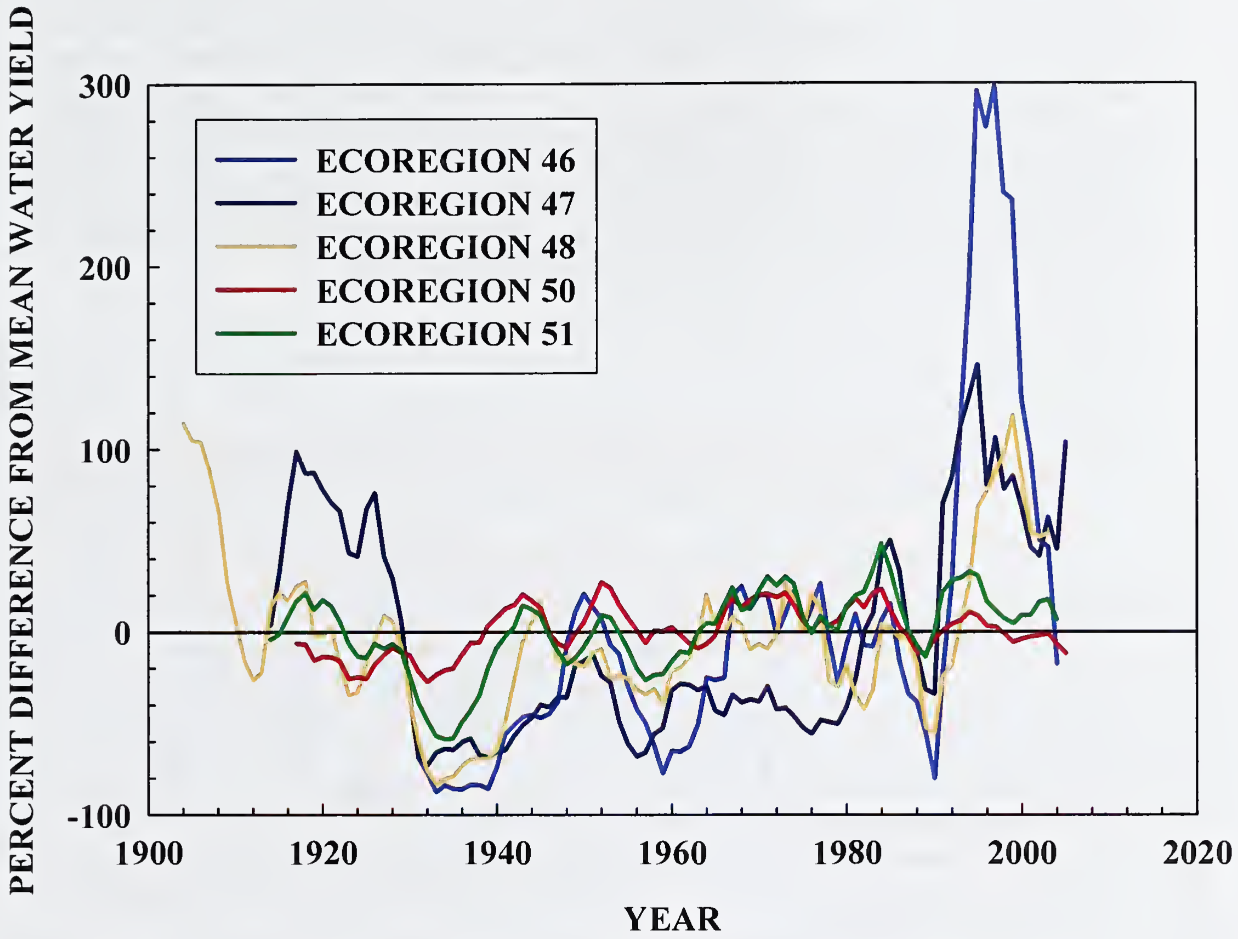


Figure 35 – Trends of percent differences in the 5-year moving averages of water yield for all of the studied ecoregions in Minnesota.

To make further inferences regarding changes in water yields over the past century, the effects of variations in precipitation were considered by investigating trends in water yield per unit of precipitation. This was done by dividing the annual water-yield data by mean-annual precipitation and should highlight water yield and runoff changes due to other controls. Results show distinct differences between ecoregions over the period of record (A) and since 1929 (B) in Figure 36 as the earliest available data for Ecoregion 46 is 1929 which therefore begins in a period of drought and is inevitably going to show an increase in water yield with time.

The most obvious feature of Figure 36 is the increase in water yield per unit of precipitation that has occurred throughout Ecoregions 46, 47, and 48 since the Dust Bowl period in the early 1930's. This trend of increasing water yield per unit of precipitation may show signs of flattening out in more recent years, perhaps since the 1990's, however more data is required to ascertain the validity of this. Ecoregions 46, 47 and 48 also show much greater variation, with major spikes and troughs in water yield per unit of precipitation. Without additional information regarding land use practices and alterations to stream channels (ie. channelization), interpretation as to the causes of this trend would be mere speculation. Figure 36 also illustrates how channels within Ecoregion 46 carried much less water than all other Ecoregions (often an order of magnitude less) until the

1970's, at which time water yield values per unit of precipitation in Ecoregion 46 are nearer to those of Ecoregions 47 and 48. It can also be seen from Figure 36 that Ecoregions 50 and 51 show very different water yield per unit of precipitation patterns than Ecoregions 46, 47 and 48. The forested and wetland Ecoregions, 50 and 51, carry more water than other studied ecoregions of Minnesota, and experience less variability and almost no increase in water yield per unit of precipitation over the period of record. At this point we cannot formally provide specific cause and effect answers to these assorted changes over the past century as they are probably the result of a number of important contributing factors, both 'natural' and human induced.

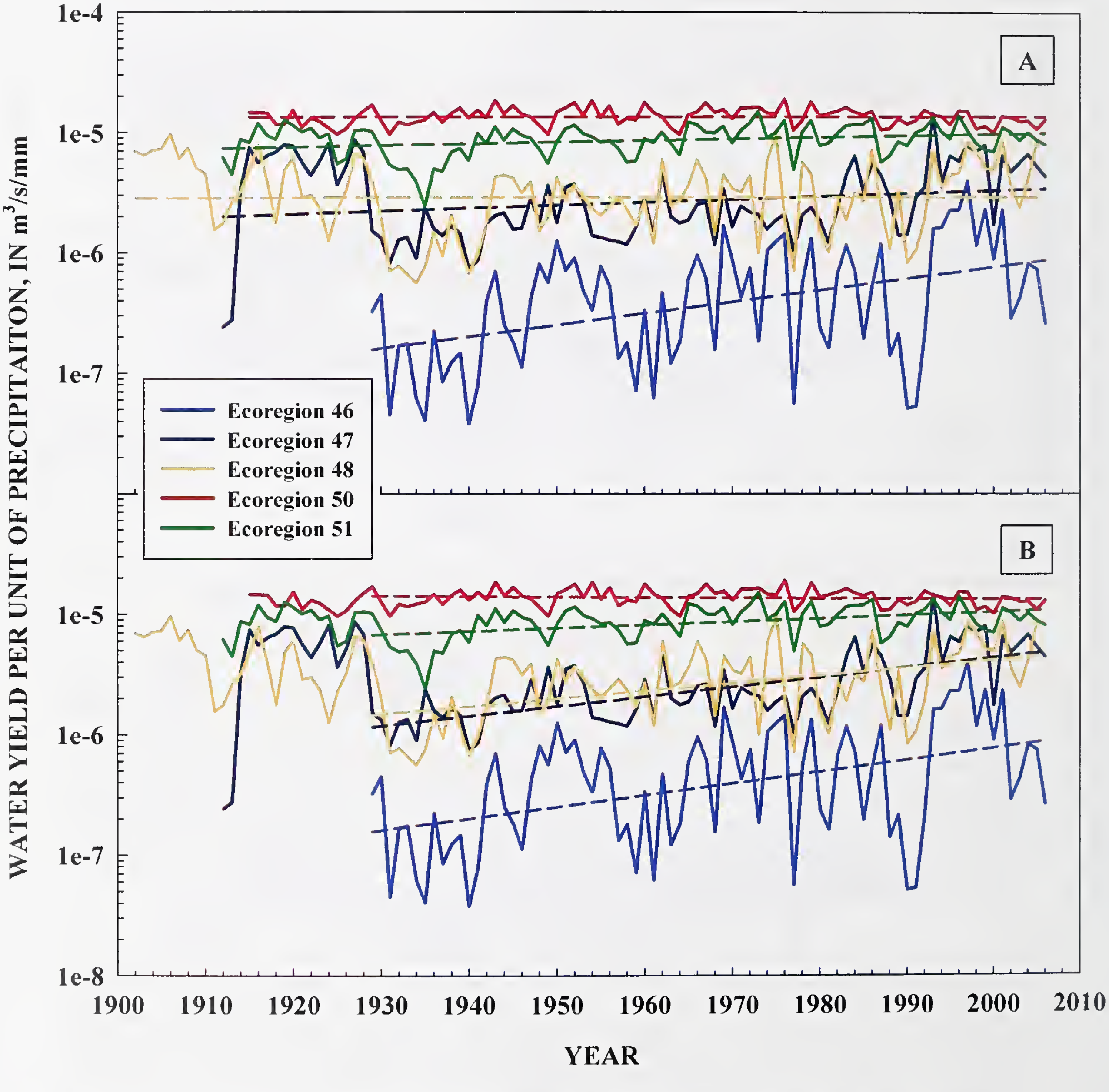


Figure 36 – Trends in average-annual water yield per unit of precipitation A) over the period of record and B) since 1929, the earliest Ecoregion 46 data, for studied ecoregions in Minnesota.

6. SUMMARY AND CONCLUSIONS

The main purpose of this study was to use scientifically-defensible methodologies by which to determine "reference" or 'target' suspended-sediment transport rates for Level III Ecoregions of Minnesota. Studied Level III Ecoregions within Minnesota include Ecoregions 46, the Northern Glaciated Plains; Ecoregion 47, The Western Corn Belt Plains; Ecoregion 48, The lake Agassiz Plain; Ecoregion 50, The Northern Lakes and Forest; and Ecoregion 51, The Northern Central Hardwood Forest. "Reference" values were obtained from analysis of the distribution of suspended-sediment loads for streams determined to be geomorphically stable at the time of suspended-sediment sampling, thus establishing 'natural' or 'background' conditions. Rapid Geomorphic Assessments carried out at current and historical USGS gaging stations found that more than half of sites visited in Ecoregions 46, 50 and 51 were considered stable, while the majority of sites in Ecoregion 47 and 48 were found to be unstable.

Load data were divided by drainage area (in km^2) so that streams of different drainage areas could be compared. All data, therefore, are expressed as suspended-sediment yields. These results were calculated for an important geomorphic discharge known as the 'effective discharge', represented by the flow that occurs, on average, once every 1.5 years ($Q_{1.5}$). These are expressed in units of $T/d/km^2$. To avoid confusion and the tendency to want to multiply the $Q_{1.5}$ value by 365 to obtain an erroneous annual value, "reference" sediment-transport rates were re-calculated using mean-daily flow data and expressed in units of $T/y/km^2$, providing a mean annual suspended-sediment yield. Ranges of "reference" suspended-sediment yield values are also provided as a more attainable goal than an absolute 'target' value.

Statistical analysis of the differences between stable and unstable sites within each Level III Ecoregion were found to be significant at the 0.05 probability level. This provides support for the overall approach of determining "reference" rates for suspended-sediment transport. Only in the case of Ecoregion 51 were stable and unstable $Q_{1.5}$ yield values not significantly different. However, when two major outliers were removed and the Mann-Whitney Rank Sum Test re-calculated, stable and unstable $Q_{1.5}$ yield values were in fact significantly statistically different. At the $Q_{1.5}$ discharge, "reference" yields range over two orders of magnitude; from 0.0039 $T/d/km^2$ for Ecoregion 46, to 0.48 $T/d/km^2$ for Ecoregion 47. Mean-annual "reference" suspended-sediment yield values also varied by two orders of magnitude, from 0.351 $T/y/km^2$ to 20.3 $T/y/km^2$ also for Ecoregions 46 and 47, respectively. Concern over the use of these results for large drainage basins was investigated by sorting "reference" data into order-of magnitude drainage-area size classes, however insufficient data was available within each size-class to establish relevant, statistically defensible trends.

To investigate the possibility of developing "reference" sediment-transport relations for each Level III Ecoregion, the initial, one-stage rating equations for each site were sorted into stable and unstable groups. In most cases, clear differences were seen between loads calculated using ratings for stable and unstable sites at a given discharge within each ecoregion. Exceptions to this were Ecoregions 48 and 51, where no distinction can be

seen in ratings from stable and unstable channels. In the case of Ecoregion 48, this inability to separate ratings from stable and unstable channels was a result of a general lack of data. Ratings were calculated using mean-daily discharge data as an insufficient number of suspended-sediment samples were available with instantaneous discharge values. Even then, the generalized rating for Ecoregion 48 was created from just five stable data sets. Differences between stable and unstable ratings were found to be statistically significant for Ecoregions 46 and 47 only; however the lack of statistical significant difference should not be over-interpreted as the power of these tests were below the desired power and therefore may be providing false negatives, most likely due to low sample populations. There seemed to be no clear 'grouping' of median "reference" rating equations between Level III Ecoregions. Ecoregions 47 and 50 had the steepest rating equation gradients, therefore channels in these ecoregions transport much higher levels of suspended-sediment proportionally during storm events, than other ecoregions of Minnesota. The rating equation for Ecoregion 46 has the lowest gradient of the five ecoregions, yet the second highest coefficient. This suggests that channels in this ecoregion transport relatively high volumes of suspended-sediment even during low flow situations, but storm response is less severe than in other areas. Differences are explained in terms of differences in physiography, boundary characteristics and land use.

All sediment-transport data were re-characterized in terms of the frequency and duration of suspended-sediment concentrations. Data in this format, sorted into stable and unstable groupings, are potentially more useful to biologists and aquatic ecologists seeking functional links between sediment transport and biological metrics. In addition, sediment 'dosage' was calculated as the product of concentration and duration and was also differentiated by stability class. Median suspended-sediment concentrations (in milligrams per liter) are lower in stable or "reference" channels at a given percent exceedance (or frequency) than in unstable channels in Ecoregions 46 and 50. Therefore, unstable channels consistently transport higher concentrations of suspended-sediment than stable channels in the both the Northern Glaciated Plains and the Northern Lakes and Forests. In Ecoregions 47, 48 and 51 this is true during moderate and high flows, those exceeded only 20 % of the time. This same pattern is evident when considering the frequency-magnitude and duration of concentration events between stable and unstable channels within each ecoregion. When median "reference" magnitude and magnitude-duration concentration values between ecoregions were compared, similar patterns were also found. Ecoregion 50 stands out as having not only the lowest storm-event (low frequency, exceeded just 0.01 % of the time) concentration of 9.9 mg/l, it also has the smallest range in concentrations between those exceeded 100 % of the time and just 0.01 % of the time (7.1 mg/l), in contrast to Ecoregion 47 with the highest low frequency concentration of 767 mg/l and the highest range in concentrations (748 mg/l).

Sediment-dosage data show distinct differences between stable and unstable sites across the range of concentrations for the most part in all Ecoregions in Minnesota. Exceptions to this occur during low frequency concentration events, or those equaled or exceeded more than 10 % of the time in Ecoregion 47, more than 50 % of the time in Ecoregion 48 and between 90 and 99 % of the time in Ecoregion 51. Ecoregion 47 has the highest dosage values, in terms of both stable and unstable channels, while Ecoregion 50 has the

lowest, and the clearest separation between stable and unstable channels. "Reference" suspended-sediment dosage peaks during frequently exceeded concentrations; those greater than 99 % of the time, low concentration events. The only exception to this is Ecoregion 46, where data are skewed by ephemeral streams. This implies that low frequency, high concentration events may have a greater affect on sediment-sensitive organisms.

The metric, 'dosage impact' represents the difference in sediment dosage for stable and unstable conditions at a given concentration exceedance and results for the studied ecoregions are difficult to interpret. The greatest sediment dose-impacts occur during low-frequency high-magnitude concentration events in Ecoregion 47, but during high-frequency low-magnitude concentration events in all other Ecoregions in Minnesota, whether impacts are positive (as in Ecoregions 46 and 50) or negative (Ecoregions 48 and 51). This suggests that impairment of biological communities due to sediment dosage may occur not only at the high flow-concentration events, but may also be linked to the generally higher concentrations that persist over long periods of time at moderate flows. The peak in dosage impact at concentrations occurring 0.1 % of the time in Ecoregion 47 (representing low-frequency high concentration events), is probably due to the increased contribution from channels sources, particularly streambanks, which become activated at higher flows.

Results of this study provide a scientifically-defensible approach by which to develop targets for sediment TMDLs in the studied Level III Ecoregions of Minnesota. These may take the form of suspended-sediment yields (load per unit area at the $Q_{1.5}$ or as annual values), frequency of occurrence of given concentrations, continuous duration of occurrence, or as a sediment 'dosage'. Different metrics may be appropriate in different settings according to the designated use and the statistical significance of the data.

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APPENDICES

Appendix A-i – Period of mean daily data and number of instantaneous peak flow data for the Northern Glaciated Plains, Ecoregion 46.

State	Gage number	Gage identification	Number of peaks	Mean Daily data	Complete years of data
ND	05058700	Sheyenne River at Lisbon	50	1956-2008	49
ND	05064900	Beaver Creek near Finley	39	1964-2003	38
ND	05099380	Pembina River near Vang	-	-	-
ND	05099400	Little South Pembina River near Walhalla	33	1956-2007	29
ND	05114000	Souris River near Sherwood	77	1930-2007	76
ND	05116000	Souris River near Foxholm	70	1936-2007	70
ND	05120000	Souris River near Verendrye	70	1937-2007	69
ND	05122000	Souris River near Bantry	70	1937-2007	69
ND	05123400	Willow Creek near Willow City	50	1956-2007	50
ND	05123500	Stone Creek near Kramer	9	1986-2000	0
ND	05123760	Deep River Below Cut Bank Creek near Upham	-	-	-
ND	05123900	Boundary Creek near Landa	36	1957-2000	23
ND	05124000	Souris River near Westhope	77	1929-2007	76
SD	05291000	Whetstone River near Big Stone City	80	1910-2007	75
SD	05292810	Labolt Impoundment Inlet at Labolt	-	-	-
MN	05293000	Yellow Bank River near Odessa	67	1939-2007	63
SD	05299670	West Branch Lac Qui Parle River near Gary	-	-	-
MN	05299750	Florida Creek near Burr	18	1982-1984	-
MN	05304500	Chippewa River near Milan	70	1937-2007	68
MN	05311000	Minnesota River at Montevideo	97	1909-2007	83
MN	05311310	Dillon-Sylte Impoundment Inlet near Porter	-	1980-1984	1
MN	05311320	Dillon-Sylte Impoundment Outlet near Porter	-	1980-1984	1
ND	06467600	James River near Manfred	38	1957-1994	30
ND	06468170	James River near Grace City	38	1968-2007	38
ND	06468250	James River above Arrowwood Lake near Kensal	21	1985-2007	21
ND	06468500	James River near Pingree	-	1952-1968	11
ND	06470000	James River at Jamestown	72	1928-2007	68
ND	06470500	James River at Lamoure	57	1950-2007	56
ND	06470830	James River at Oakes	-	1982-2005	0
ND	06470875	James River at Dakota Lake Dam near Ludden	20	2002-2008	2
SD	06470980	James River near Hecla	-	1985-1986	0
SD	06471000	James River at Columbia	60	1945-2007	28
SD	06473000	James River at Ashton	60	1945-2007	52
SD	06478500	James River near Scotland	78	1928-2007	78
SD	06479529	Stray Horse Creek near Castlewood	17	1968-1985	16
SD	06479640	Hidewood Creek near Estelline	34	1968-1985	16
SD	06480000	Big Sioux River near Brookings	53	1953-2007	52
SD	06481500	Skunk Creek at Sioux Falls	56	1948-2007	54
MN	443636096095402	Dillon-Sylte Impoundment Inlet near Porter	-	-	-
MN	443916096174801	Lac Qui Parle River (Lqp-8) near Canby	-	1982-1984	1

Appendix B-ii – Period of mean daily data and number of instantaneous peak flow data for the Western Corn Belt Plains, Ecoregion 47.

State	Gage number	Gage identification	Number of peak flow data	Mean-daily data	Complete years of data
MN	05316500	Redwood River near Redwood Falls	62	1909-2006	70
MN	05319500	Watonwan River near Garden City	37	1940-2006	32
MN	05320270	Little Cobb River near Beauford	53	1996-2006	6
MN	05320300	Cobb River Tributary near Mapleton	103	-	-
MN	05320500	Le Sueur River near Rapidan	37	1939-2006	60
MN	05322000	Minnesota River at Mankato	113	-	-
MN	05325000	Minnesota River at Mankato	96	1903-2006	84
IA	05418500	Maquoketa River near Maquoketa	36	1913-2006	92
IA	05420680	Wapsipinicon River near Tripoli	75	1996-2006	5
IA	05422000	Wapsipinicon River near De Witt	66	1934-2006	71
IA	05449500	Iowa River near Rowan	96	1940-2006	63
IA	05451210	South Fork Iowa River Ne Of New Providence	104	1995-2006	10
IA	05451500	Iowa River at Marshalltown	46	1902-2006	85
IA	05453100	Iowa River at Marengo	45	1956-2008	51
IA	05454500	Iowa River at Iowa City	78	1903-2008	102
IA	05455100	Old Mans Creek near Iowa City	42	1950-2008	36
MN	05457000	Cedar River near Austin	34	1909-2008	66
IA	05461390	Flood Creek near Powersville	35	-	2
IA	05463050	Cedar River at Cedar Falls	65	-	2
IA	05464220	Wolf Creek near Dysart	54	1995-2008	8
IA	05471050	South Skunk River at Colfax	35	1985-2008	22
IA	05481650	Des Moines River near Saylorville	154	1961-2008	46
IA	05483450	Middle Raccoon River near Bayard	50	1979-2008	28
IA	05483600	Middle Raccoon River at Panora	38	1958-2008	49
IA	05484500	Raccoon River at Van Meter	38	1915-2008	92
IA	06485500	Big Sioux River at Akron	181	1915-2006	76
NE	06486000	Missouri River at Sioux City	823	1928-2006	69
NE	06610000	Missouri River at Omaha	844	1928-2006	77
NE	06796000	Platte River at North Bend	48	1949-2006	56
NE	06798500	Elkhorn River at Neligh	62	1930-1993	59
NE	06799000	Elkhorn River at Norfolk Ne	68	1900-2006	60
NE	06799450	Logan Creek at Pender Ne	62	1965-1993	27
NE	06800000	Maple Creek near Nickerson	222	1951-2006	54
NE	06800500	Elkhorn River at Waterloo	223	1928-2006	77
NE	06803555	Salt Creek at Greenwood	46	1951-2006	54
NE	06805500	Platte River at Louisville Ne	417	1953-2006	52
NE	06807000	Missouri River at Nebraska City	729	1929-2006	76
IA	06810000	Nishnabotna River Above Hamburg	67	1922-2006	77
NE	06810900	Brownell Creek subwatershed 1A near Syracuse	62	1955-1969	13
NE	06811000	Brownell Creek Subwatershed 1 near Syracuse	61	1954-1969	14
KS	06815274	Walnut Creek near Fairview	37	-	-
KS	06815280	Mulberry Creek near Fairview	33	-	-
KS	06815288	Walnut Creek near Hamlin	46	-	-
KS	06815290	Terrapin Creek at Hamlin	33	-	-
KS	06815300	Walnut Creek at Reserve	91	-	-
KS	06815570	Wolf River 3 Miles Sw Of Hiawatha	80	-	-
KS	06815578	Wolf River at Hiawatha	142	-	-
KS	06815700	Buttermilk Creek near Willis	105	-	-
KS	06815800	Wolf River at Leona	77	-	-
KS	06815880	Wolf River near Sparks	159	-	-

State	Gage number	Gage identification	Number of peak flow data	Mean-daily data	Complete years of data
IA	06817000	Nodaway River at Clarinda	154	1918-2006	70
MO	06818000	Missouri River at St. Joseph	319	1928-2006	77
MO	06821190	Platte River at Sharps Station	72	1978-2006	27
NE	06882000	Big Blue River at Barneston Nebr	71	1932-2006	73
KS	06885500	Black Vermillion River near Frankfort	88	1953-2006	51
KS	06889100	Soldier Creek near Goff	44	1964-1987	22
KS	06889120	Soldier Creek near Bancroft	58	1964-1988	23
KS	06889140	Soldier Creek near Soldier	39	1964-1998	33
KS	06889160	Soldier Creek near Circleville	72	1964-2001	36
KS	06890000	L Delaware River near Horton	120	1954-1978	8
KS	06890096	L Grasshopper Creek at Muscotah	36	-	-
KS	06890100	Delaware River near Muscotah	183	1969-2006	35
MO	06893000	Missouri River at Kansas City	112	1928-2006	77

Appendix C-iii – Period of mean daily data and number of instantaneous peak flow data for the Lake Agassiz Plain, Ecoregion 48.

State	Gage number	Gage identification	Number of peaks	Mean Daily data	Complete years of data
MN	05030150	Otter Tail River near Perham	-	1993-1994	0
ND	05051522	Red River of the North at Hickson	30	1975-2006	30
ND	05053000	Wild Rice River near Abercrombie	73	1932-2006	73
ND	05054020	Red River of the North below Fargo	-	-	-
ND	05059000	Sheyenne River near Kindred	57	1949-2006	56
MN	05062500	Wild Rice River at Twin Valley	85	1945-2007	75
MN	05064000	Wild Rice River at Hendrum	63	1944-2006	59
MN	05064500	Red River of the North at Halstad	66	1961-2006	44
MN	05079000	Red Lake River at Crookston	104	1901-2007	105
ND	05082625	Turtle River at Turtle River State Park near Arvilla	13	1992-2006	13
MN	05083500	Red River of the North at Olso	43	1936-1976	2
MN	05085900	Snake River above Alvarado	4	1992-1996	3
ND	05099600	Pembina River at Walhalla	59	1939-2007	56
ND	05102490	Red River of the North at Pembina	21	-	-
MN	05061000	Buffalo River near Hawley	63	1945-2007	54
MN	05061500	South Branch Buffalo River at Sabin	62	1945-2007	54
MN	05062000	Buffalo River near Dilworth	76	1931-2007	74
MN	05087500	Middle River at Argyle	58	1945-2007	54

Appendix D-iv – Period of mean daily data and number of instantaneous peak flow data for the Northern Lakes and Forest, Ecoregion 50.

State	Gage number	Gage identification	Number of peak flow data	Mean-daily data	Complete years of data
MI	04001000	Washington Creek at Windingo	39	1964-2003	38
MN	04014500	Baptism River near Beaver Bay	63	1928-1993	59
MN	04024000	St. Louis River at Scanlon	99	1908-2008	98
WI	04024314	Little Balsam Creek at Patzau	-	1976-1978	1
WI	04024315	Little Balsam Creek near Patzau	-	1975-1978	2
WI	04024318	Little Balsam Creek Tributary near Patzau	-	1976-1978	1
WI	04024320	Little Balsam Creek near Foxboro	-	1977-1978	-
WI	04024430	Nemadji River near South Superior	32	1973-2008	32
WI	04025500	Bois Brule River at Brule	62	1942-2008	60
WI	04026005	Bois Brule River near Lake Superior	-	-	-
WI	04026190	Sand River near Red Cliff	-	1979-1985	2
WI	04026346	North Fish Creek near Benoit	-	-	-
WI	04026347	Pine Creek at Moquah	-	1975-1978	2
WI	04026348	Pine Creek Tributary at Moquah	-	1976-1978	1
WI	04026349	Pine Creek near Moquah	-	1975-1978	2
WI	040263491	North Fish Creek near Moquah	11	1989-2008	9
WI	04026350	North Fish Creek near Ashland	-	-	-
WI	04026870	Alder Creek near Upson	3	1972-1977	4
WI	04027000	Bad River near Odanah	64	-	-
WI	04027496	White River near Sanborn	-	1976-1976	0
WI	04027500	White River near Ashland	58	1948-2008	58
WI	04027595	Bad River at Odanah	-	-	-
MI	04040000	Ontonagon River near Rockland	65	1942-2008	63
MI	04043004	Sturgeon River near Chassell	-	-	-
MI	04045500	Tahquamenon River near Paradise	53	1953-2008	53
MI	04057004	Manistique River above Manistique	-	1992-1995	2
MI	04059000	Escanaba River at Cornell	61	1903-2008	55
MI	040590345	Escanaba River at Wells	-	1988-1990	1
MI	04059500	Ford River near Hyde	52	1954-2008	51
WI	04061000	Brule River near Florence	51	1914-1994	50
MI	04062085	Peshekee River near Martins Landing	-	-	-
WI	04063700	Popple River near Fence	43	1963-2008	43
WI	04066500	Pike River at Amberg	62	1914-2008	60
WI	04067500	Menominee River near McAllister	54	1945-2008	32
WI	04067651	Menominee River at Mouth at Marinette	-	1988-1995	0
WI	04074548	Swamp Creek Below Rice Lake at Mole Lake	4	1977-2008	7
MI	04123910	Anderson Creek near Buckley	-	-	-
MI	04125210	Silver Creek near Luther	-	1968-1970	1
MI	04125350	Poplar Creek near Hoxeyville	-	1968-1970	1
MI	04125450	Pine River near Dublin	-	1967-1970	2
MI	04125510	Pine River near Wellston	-	1966-1970	3
MI	04126970	Boardman River above Brown Bridge Road near Mayfield	9	1997-2008	10
MI	04126991	Boardman River near Mayfield	-	-	-

State	Gage number	Gage identification	Number of peak flow data	Mean-daily data	Complete years of data
MI	04126997	East Creek at Green Road near Mayfield	-	-	-
MI	04127008	Swainston Creek at Mayfield	-	-	-
MI	04132052	Cheboygan River (Pond) at Lincoln Ave at Cheboygan	-	1985-1992	4
MI	04132300	Hunt Creek at Hunt Creek Road near Lewiston	-	-	-
MI	04135000	Thunder Bay River near Alpena	20	1901-1993	20
MI	04135470	Au Sable River at Pollack Br near Grayling	-	-	-
MI	04135475	Au Sable River at Old Dam Road near Grayling	-	-	-
MI	04137500	Au Sable River near Au Sable	19	1978-2008	20
MI	04142000	Rifle River near Sterling	70	1937-2008	70
MN	05124480	Kawishiwi River near Ely	40	1966-2008	41
MN	05125550	Stony River near Babbitt	26	1975-1980	4
MN	05216820	Initial Tailings Basin Outfall near Keewatin	3	1982-1985	2
MN	05284305	Seguchie Creek at Holt Lake Outlet, near Garrison	3	-	-
MN	05284310	Seguchie Creek above Mouth near Garrison	2	-	-
WI	05331833	Namekagon River at Leonards	6	1996-2008	5
WI	05331855	Namekagon River near Hayward	-	-	-
WI	05332500	Namekagon River near Trego	60	1927-2006	60
WI	05333500	St. Croix River near Danbury	89	1914-2008	87
WI	05335031	Yellow River at Danbury	-	-	-
WI	05335500	Clam River near Webster	-	1940-1942	1
WI	05340390	Trade River near Trade River	-	1998-1999	-
WI	05357335	Bear River near Manitowish Waters	13	1991-2006	14
WI	05359500	South Fork Flambeau River near Phillips	47	1929-1975	34
WI	05367154	Sucker Creek at Loch Lomond Blvd near Birchwood	-	2000-2001	-
WI	05367190	Hemlock Creek at County Trunk Hghwy F near Mikana	-	2000-2001	-
WI	05393500	Spirit River at Spirit Falls	64	1942-2007	63

Appendix E-v – Period of mean daily data and number of instantaneous peak flow data for the Northern Central Hardwood Forest, Ecoregion 51.

State	Gage number	Gage identification	Number of peak flow data	Mean-daily data	Complete years of data
WI	04071000	Oconto River near Gillett	36	1906-2008	94
WI	04071795	Pensaukee River near Krakow	36	1993-1995	1
WI	04071858	Pensaukee River near Pensaukee	142	1972-1996	23
WI	04072233	Lancaster Brook at Shawano Ave at Horward	82	-	-
WI	04075365	Evergreen River below Evergreen Falls near Langlade	43	2002-2006	3
WI	04077630	Red River at Morgan Road near Morgan	226	1992-2008	13
WI	04078500	Embarrass River near Embarrass	31	1919-2008	77
WI	04080798	Tomorrow River near Nelsonville	36	1993-1995	1
WI	04085200	Kewaunee River near Kewaunee	160	1964-2008	38
MI	04126520	Manistee River at Manistee	141	-	-
MI	04126546	Green Lake Inlet near Interlochen	19	-	-
MI	04127250	Boardman River at Cass Road near Traverse City	21	-	-
MI	04127490	Boardman River at Traverse City	21	-	-
MI	04127498	Hospital Creek at Traverse City	21	-	-
MI	04127520	Mitchell Creek at Traverse City	21	-	-
MI	04127528	Acme Creek at HWY 31 at Acme	20	-	-
MI	04127535	Yuba Creek near Acme	21	-	-
MI	04127550	Tobeco Creek near Elk Rapids	19	-	-
MI	04127600	Battle Creek near Williamsburg	21	-	-
MI	04127620	Williamsburg Creek at Ayers Road near Williamsburg	21	-	-
MN	05030150	Otter Trail River near Perham	30	1993-1994	1
MN	05030181	Otter Trail River at Little Pine Lake OTL near Perham	8	-	-
MN	05030270	Toad River at Big Pine Lake Inlet near Perham	24	-	-
MN	05030290	Otter Trail River at Big Pine Lake Outlet near Perham	19	-	-
MN	05267000	Mississippi River near Royalton	100	1924-2008	81
MN	05275000	Elk River near Big Lake	23	1911-2008	72
MN	05276005	North Fork Crow River above Paynesville	35	1996-1999	1
MN	05288500	Mississippi River near Aonoka	29	1931-2008	74
MN	05288705	Shingle Creek at Queen Avenue in Minneapolis	121	1996-2008	6
MN	05330000	Minnesota River near Jordan	179	1934-2007	72
MN	05330902	Nine Mile Creek near James Circle at Bloomington	55	-	-
MN	05331000	Mississippi River at St. Paul	36	1892-2006	103
MN	05338500	Snake River near Pine City	27	1951-2008	45
WI	05338955	Wood River at North Williams Road near Grantsburg	21	-	-
WI	05340500	St. Croix River at St. Croix Falls	166	1902-2008	100
WI	05341500	Apple River near Somerset	18	1914-2006	74
WI	05364850	Duncan Creek Tributary near Tilden	267	1986-1989	2
WI	05367055	Chippewa River near Caryville	86	-	-
WI	05368000	Hay River at Wheeler	80	1950-2008	55
WI	05381350	Levis Creek at Black River Falls	16	-	-
WI	05394500	Prairie River near Merrill	8	1914-2008	83
WI	05397500	Eau Claire River at Kelly	34	1914-2008	78
WI	05399500	Big Eau Pleine River at Stratford	286	1914-2008	79
WI	05399550	Fenwood Creek at Bradley	37	-	-
WI	05399580	Fenwood Creek at Halder	40	-	-
WI	05399600	Big Eau Pleine River near Knowlton	466	-	-
WI	05400650	Little Plover River at Plover	32	1959-1987	27
WI	05401050	Tenmile Creek near Nekoosa	62	1963-2008	29
WI	05401535	Big Roche A Cri Creek near Adams	24	1963-1978	14
WI	05402000	Yellow River at Babcock	8	1944-2008	59
WI	05403500	Lemonweir River at New Lisbon	175	1944-1994	42
WI	05403630	Hulbert Creek near Wisconsin Dells	41	1970-1977	6

Appendix B-i – Location of USGS gages with suspended-sediment data and transport rating relations in the Northern Glaciated Plains, Ecoregion 46.

State	Gage number	Gage identification	Latitude	Longitude	Number of suspended sediment samples	Load Coefficient	Load Exponent	First sample	Last sample
ND	05058700	Sheyenne River at Lisbon	47.199112	-112.09639	39	1.7045	1.6446	5/6/1977	6/20/1995
ND	05064900	Beaver Creek near Finley	47.50245	-111.93249	78	2.8029	1.1321	10/31/1973	12/13/1995
ND	05099380	Pembina River near Vang	47.624957	-111.63554	66	12.89	1.4297	12/18/1973	9/26/1979
ND	05099400	Little South Pembina River near Walhalla	47.560791	-111.54136	78	17.06	1.6661	12/19/1973	8/21/1995
ND	05114000	Souris River near Sherwood	47.525791	-111.51192	61	2.6253	1.2439	4/16/1974	10/6/1981
ND	05116000	Souris River near Foxholm	47.58441	-111.06052	80	1.0064	1.0781	2/27/1974	9/4/1980
ND	05120000	Souris River near Verendrye	47.587189	-111.03191	92	1.5863	1.1904	10/18/1976	8/25/1986
ND	05122000	Souris River near Bantry	47.642467	-110.93357	30	1.4663	1.2081	12/5/1985	11/14/2000
ND	05123400	Willow Creek near Willow City	47.81747	-110.66716	12	1.0395	0.9241	3/25/1986	4/28/1989
ND	05123500	Stone Creek near Kramer	48.306371	-111.08053	24	2.8528	1.2356	3/28/1986	6/27/2000
ND	05123760	Deep River Below Cut Bank Creek near Upham	47.883006	-112.61198	1	-	-	-	-
ND	05123900	Boundary Creek near Landa	47.930241	-111.55276	23	1.7871	1.1707	3/26/1986	6/27/2000
ND	05124000	Souris River near Westhope	47.932472	-110.51438	139	2.1292	0.8409	10/17/1974	4/6/1994
SD	05291000	Whetstone River near Big Stone City	48.004973	-110.25771	495	5.3646	1.1308	10/2/1960	7/5/1988
SD	05292810	Labolt Impoundment Inlet at Labolt	48.044185	-106.35642	28	9.8304	1.5202	3/19/1980	6/22/1984
MN	05293000	Yellow Bank River near Odessa	48.301933	-109.84437	139	7.8077	1.1365	10/2/1960	6/29/1988
SD	05299670	West Branch Lac Qui Parle River near Gary	48.526663	-109.8416	29	6.6717	1.4362	3/4/1982	6/15/1984
MN	05299750	Florida Creek near Burr	48.031107	-108.53265	47	8.2864	1.48	3/17/1982	9/5/1984
MN	05304500	Chippewa River near Milan	48.363608	-108.35625	104	5.6458	1.1614	10/3/1960	8/13/1981
MN	05311000	Minnesota River at Montevideo	48.969467	-106.8395	61	2.9872	1.2464	8/15/1989	3/4/1993
MN	05311310	Dillon-Sylte Impoundment Inlet near Porter	48.129742	-106.36448	34	6.3658	1.1974	3/20/1980	6/15/1984
MN	05311320	Dillon-Sylte Impoundment Outlet near Porter	47.998906	-105.86723	28	2.7463	1.0246	3/20/1980	6/15/1984
ND	06467600	James River near Manfred	47.630846	-105.3286	32	0.7647	0.924	5/13/1985	7/26/1995
ND	06468170	James River near Grace City	47.901961	-105.21554	54	1.1549	0.9546	5/14/1985	8/29/1995
ND	06468250	James River above Arrowwood Lake near Kensal	48.990302	-105.69667	132	2.3755	0.9423	6/26/1985	9/6/2005
ND	06468500	James River near Pingree	48.873079	-105.49778	8	1.9983	0.7395	10/9/1986	4/4/2001

State	Gage number	Gage identification	Latitude	Longitude	Number of suspended sediment samples	Load Coefficient	Load Exponent	First sample	Last sample
ND	06470000	James River at Jamestown	48.9994	-105.4089	79	3.1172	0.9182	1/9/1985	8/31/1995
ND	06470500	James River at Lamoure	48.852246	-105.42138	135	4.4918	1.0465	10/5/1976	8/31/1995
ND	06470830	James River at Oakes	48.551412	-105.36582	14	5.0558	1.0045	4/1/1986	4/4/1989
ND	06470875	James River at Dakota Lake Dam near Ludden	49.000025	-106.36726	66	3.5098	0.9675	1/8/1985	8/30/1995
SD	06470980	James River near Hecla	48.550301	-105.42888	22	2.9857	1.0418	1/8/1985	4/4/1989
SD	06471000	James River at Columbia	48.170852	-105.17887	73	3.5199	0.8167	4/13/1979	8/18/1993
SD	06473000	James River at Ashton	48.672805	-104.51218	30	8.5399	0.8735	2/27/1985	7/19/1990
SD	06478500	James River near Scotland	47.746683	-104.3305	161	10.489	0.9956	10/8/1974	8/31/1995
SD	06479529	Stray Horse Creek near Castlewood	47.30333	-101.08932	30	9.4617	1.06	9/1/1970	6/4/1974
SD	06479640	Hidewood Creek near Estelline	43.064995	-98.553416	31	9.2064	0.9544	9/1/1970	7/10/1974
SD	06480000	Big Sioux River near Brookings	43.097771	-98.287856	43	8.8206	1.0086	9/1/1970	8/13/2003
SD	06481500	Skunk Creek at Sioux Falls	43.02555	-98.167854	35	9.8573	1.0564	9/3/1970	9/6/1974
MN	443636096095402	Dillon-Sylte Impoundment Inlet near Porter	42.861109	-98.140631	-	-	-	-	-
MN	443916096174801	Lac Qui Parle River (Lqp-8) near Canby	42.9403	-98.8417	45	4.898	1.25	3/17/1982	7/13/1984

Appendix B-ii – Location of USGS gages with suspended-sediment data and transport rating relations in the Western Corn Belt Plains, Ecoregion 47.

State	Gage number	Gage identification	Latitude	Longitude	Number of suspended-sediment samples	Load coefficient	Load exponent	First sample	Last sample
MN	05316500	Redwood River near Redwood Falls	44.52357	-95.1724992	62	11.6	1.249	10/3/1960	6/21/1993
MN	05319500	Watonwan River near Garden City	44.046352	-94.1955144	37	2.67	1.536	3/17/1977	4/23/1992
MN	05320270	Little Cobb River near Beauford	43.996633	-93.9085628	53	8.2366	1.1722	3/14/1996	9/7/2005
MN	05320300	Cobb River Tributary near Mapleton	44.018021	-93.958564	103	16	1.424	3/7/1995	8/26/1997
MN	05320500	Le Sueur River near Rapidan	44.111077	-94.0413447	37	3.05	1.68	8/28/1989	8/8/1992
MN	05322000	Minnesota River at Mankato	44.163299	-94.0369006	113	1.8903	1.5307	8/29/1989	8/26/1997
MN	05325000	Minnesota River at Mankato	44.168855	-94.0032886	96	2.0669	1.414	10/4/1960	9/8/2000
IA	05418500	Maquoketa River near Maquoketa	42.083353	-90.6329124	36	0.0765	2.6264	3/18/1975	3/16/1995
IA	05420680	Wapsipinicon River near Tripoli	42.836091	-92.2574003	75	0.9482	1.3707	3/27/1996	8/3/2004
IA	05422000	Wapsipinicon River near De Witt	41.766974	-90.5348588	66	1.1104	1.5983	3/18/1975	9/8/2005
IA	05449500	Iowa River near Rowan	42.759944	-93.6218489	96	4.7144	1.2045	5/22/1985	8/2/2004
IA	05451210	South Fork Iowa River Ne Of New Providence	42.314984	-93.1524252	104	4.6729	1.412	3/19/1996	8/2/2005
IA	05451500	Iowa River at Marshalltown	42.065821	-92.9076997	46	2.36	1.525	6/14/1984	11/29/1994
IA	05453100	Iowa River at Marengo	41.812726	-92.064792	45	3.21	1.405	3/19/1975	9/4/1998
IA	05454500	Iowa River at Iowa City	41.656683	-91.5410017	78	0.684	1.632	4/29/1974	9/1/1987
IA	05455100	Old Mans Creek near Iowa City	41.606405	-91.6157242	42	3.9572	1.9024	3/18/1975	11/10/1999
MN	05457000	Cedar River near Austin	43.637185	-92.9746369	34	0.922	1.772	3/30/1962	8/22/1980
IA	05461390	Flood Creek near Powersville	42.907196	-92.7207472	35	2.425	1.3178	3/28/1996	7/22/1999
IA	05463050	Cedar River at Cedar Falls	42.538873	-92.449632	65	0.1913	1.6995	5/23/1984	11/14/2000
IA	05464220	Wolf Creek near Dysart	42.251658	-92.2987976	54	1.942	1.8397	3/21/1996	11/15/2000
IA	05471050	South Skunk River at Colfax	41.681378	-93.2465939	35	0.838	1.907	3/16/1989	9/8/1993
IA	05481650	Des Moines River near Saylorville	41.680544	-93.6682755	154	0.8716	1.3312	4/21/1974	9/17/2004
IA	05483450	Middle Raccoon River near Bayard	41.778597	-94.4927492	50	7.46	1.969	4/12/1979	8/5/1985
IA	05483600	Middle Raccoon River at Panora	41.687209	-94.3710773	38	2.22	1.33	4/12/1979	6/20/1985
IA	05484500	Raccoon River at Van Meter	41.533878	-93.9499503	38	0.766	1.813	12/16/1986	8/10/1994
IA	06485500	Big Sioux River at Akron	42.837215	-96.5616997	181	7.0424	1.3107	9/18/1970	8/9/2005
NE	06486000	Missouri River at Sioux City	42.485828	-96.4139184	823	5.4	1.2	4/26/1909	9/26/1991
NE	06610000	Missouri River at Omaha	41.258887	-95.9225138	844	0.0004	2.63	10/1/1973	9/1/1998
NE	06796000	Platte River at North Bend	41.452778	-96.7755556	48	0.922	1.803	6/30/1970	8/7/1981
NE	06798500	Elkhorn River at Neligh	42.125	-98.0311111	62	1.9	2.04	3/28/1950	10/30/1975
NE	06799000	Elkhorn River at Norfolk Ne	42.003778	-97.4260278	68	1.12	2.24	10/11/1966	9/15/1992
NE	06799450	Logan Creek at Pender Ne	42.113889	-96.7016667	62	4.54	2.19	10/19/1966	7/5/1979
NE	06800000	Maple Creek near Nickerson	41.560278	-96.5408333	222	11.837	2.2442	5/12/1992	8/9/2005
NE	06800500	Elkhorn River at Waterloo	41.293333	-96.2838889	223	0.31	2.3155	11/23/1948	8/11/2004

State	Gage number	Gage identification	Latitude	Longitude	Number of suspended-sediment samples	Load coefficient	Load exponent	First sample	Last sample
NE	06803555	Salt Creek at Greenwood	40.965556	-96.4544444	46	6.6578	1.8077	4/4/1975	7/15/2002
NE	06805500	Platte River at Louisville Ne	41.015278	-96.1577778	417	0.3389	1.9467	10/9/1974	8/10/2005
NE	06807000	Missouri River at Nebraska City	40.681946	-95.846946	729	0.236	1.74	10/1/1973	9/24/1991
IA	06810000	Nishnabotna River Above Hamburg	40.632501	-95.625826	67	0.5741	2.1361	11/21/1983	8/11/2005
NE	06810900	Brownell Creek subwatershed 1A near Syracuse	40.671113	-96.1255635	62	178	1.194	6/24/1955	6/14/1967
NE	06811000	Borwnell Creek Subwatershed 1 near Syracuse	40.672502	-96.1277857	61	61.2	1.175	6/24/1955	6/14/1967
KS	06815274	Walnut Creek near Fairview	39.838057	-95.6391508	37	26.6	2.09	6/28/1976	8/20/1979
KS	06815280	Mulberry Creek near Fairview	39.866668	-95.655818	33	75.2	2	6/12/1964	5/25/1971
KS	06815288	Walnut Creek near Hamlin	39.899447	-95.593317	46	78.4	1.458	5/19/1977	8/20/1979
KS	06815290	Terrapin Creek at Hamlin	39.881113	-95.6255397	33	64.5	1.937	6/12/1964	5/25/1971
KS	06815300	Walnut Creek at Reserve	39.972225	-95.553039	91	129	1.276	5/16/1963	11/17/1988
KS	06815570	Wolf River 3 Miles Sw Of Hiawatha	39.815836	-95.5641492	80	155	1.548	4/9/1978	6/24/1980
KS	06815578	Wolf River at Hiawatha	39.792781	-95.526926	142	104	1.524	3/11/1977	6/24/1980
KS	06815700	Buttermilk Creek near Willis	39.754448	-95.450813	105	135	1.452	3/11/1977	6/23/1980
KS	06815800	Wolf River at Leona	39.781389	-95.3213657	77	35.8	1.786	6/29/1976	7/2/1980
KS	06815880	Wolf River near Sparks	39.82222	-95.1919189	159	31.6	1.784	6/29/1976	10/8/1980
IA	06817000	Nodaway River at Clarinda	40.739435	-95.0133123	154	2.25	2.16	2/17/1976	9/9/1992
MO	06818000	Missouri River at St. Joseph	39.75325	-94.8568333	319	0.6074	1.623	10/4/1977	6/22/1993
MO	06821190	Platte River at Sharps Station	39.400972	-94.7268333	72	2.81	1.749	3/20/1979	6/15/1995
NE	06882000	Big Blue River at Barneston Nebr	40.044722	-96.5872222	71	0.445	2.1	7/2/1986	9/13/1993
KS	06885500	Black Vermillion River near Frankfort	39.681943	-96.4427888	88	10.238	1.6309	4/22/1976	6/9/2003
KS	06889100	Soldier Creek near Goff	39.624163	-95.9661053	44	179	1.745	10/3/1972	5/31/1980
KS	06889120	Soldier Creek near Bancroft	39.594757	-95.973919	58	56	1.702	10/3/1972	4/3/1980
KS	06889140	Soldier Creek near Soldier	39.565829	-95.962771	39	24	1.804	10/3/1972	5/31/1980
KS	06889160	Soldier Creek near Circleville	39.463145	-95.9505944	72	22.5	1.829	10/4/1972	6/1/1989
KS	06890000	L Delaware River near Horton	39.696238	-95.5639147	120	74.5	1.267	6/28/1976	9/20/1978
KS	06890096	L Grasshopper Creek at Muscotah	39.547222	-95.5141448	36	163	1.0048	5/6/1977	9/21/1978
KS	06890100	Delaware River near Muscotah	39.521387	-95.532756	183	9.7771	1.7092	5/23/1977	2/23/2004
MO	06893000	Missouri River at Kansas City	39.111722	-94.5881389	112	0.0002	2.75	7/24/1989	9/18/1991

Appendix B-iii – Location of USGS gages with suspended-sediment data and transport rating relations in the Lake Agassiz Plain, Ecoregion 48.

State	Gage number	Gage identification	Latitude	Longitude	Number of suspended sediment samples	Load Coefficient	Load Exponent	First sample	Last sample
MN	05030150	Otter Tail River near Perham	46.642737	-95.604486	30	0.248	1.5042	4/1/1993	5/1/1996
ND	05051522	Red River of the North at Hickson	46.659685	-96.795915	81	1.9226	1.3047	11/3/1975	9/2/1999
ND	05053000	Wild Rice River near Abercrombie	46.468017	-96.783691	61	3.8254	1.1548	7/4/1975	7/7/1994
ND	05054020	Red River of the North below Fargo	46.930520	-96.785080	48	2.185	1.263	10/19/1973	9/20/1977
ND	05059000	Sheyenne River near Kindred	46.631633	-97.000643	104	3.1029	1.5119	7/3/1975	8/10/1995
MN	05062500	Wild Rice River at Twin Valley	47.266629	-96.244780	48	0.4908	1.9032	4/5/1993	3/19/2001
MN	05064000	Wild Rice River at Hendrum	47.268027	-96.797578	32	5.2306	1.2568	4/20/1979	4/17/2001
MN	05064500	Red River of the North at Halstad	47.351918	-96.843691	130	0.941	1.5858	4/11/1962	5/11/1995
MN	05079000	Red Lake River at Crookston	47.775527	-96.609510	110	0.9487	1.3205	4/11/1962	4/20/2001
ND	05082625	Turtle River at Turtle River State Park near Arvilla	47.931934	-97.514531	48	1.4356	1.6949	2/8/1993	7/12/2000
MN	05083500	Red River of the North at Olso	48.193873	-97.140628	49	0.4631	1.5486	10/17/1973	12/13/1977
MN	05085900	Snake River above Alvarado	48.174148	-96.998960	24	4.6354	1.3527	5/24/1993	4/20/1996
ND	05099600	Pembina River at Walhalla	48.913328	-97.917037	115	10.24	1.514	4/16/1974	8/21/1995
ND	05102490	Red River of the North at Pembina	48.973599	-97.241731	4	367.84	0.5387	7/19/1994	9/9/1999
MN	05061000	Buffalo River near Hawley	46.849960	-96.329509	403	0.1215	0.8519	3/22/1977	9/30/1978
MN	05061500	South Branch Buffalo River at Sabin	46.772184	-96.628132	371	1.9515	1.0055	3/21/1977	9/30/1978
MN	05062000	Buffalo River near Dilworth	46.961074	-96.661465	748	6.868	0.9694	3/30/1971	9/24/1981
MN	05087500	Middle River at Argyle	48.340255	-96.816450	307	2.6013	1.1741	3/25/1968	7/22/1970

Appendix B-iv – Location of USGS gages with suspended-sediment data and transport rating relations in the Northern Lakes and Forest, Ecoregion 50.

State	Gage number	Gage identification	Latitude	Longitude	Number of suspended-sediment samples	Load coefficient	Load exponent	First sample	Last sample
MI	04001000	Washington Creek at Windingo	47.9231000	-89.1450000	107	0.6498	1.2642	8/6/1962	8/2/2001
MN	04014500	Baptism River near Beaver Bay	47.3375000	-91.2006000	103	0.3001	1.2572	10/31/1974	7/20/1993
MN	04024000	St. Louis River at Scanlon	46.7033000	-92.4186000	127	0.0789	1.6075	10/30/1974	8/1/1994
WI	04024314	Little Balsam Creek at Patzau	46.4953000	-92.2297000	301	10.111	2.1022	1/28/1976	7/7/1978
WI	04024315	Little Balsam Creek near Patzau	46.5036000	-92.2347000	291	11.53	2.1605	9/27/1975	9/13/1978
WI	04024318	Little Balsam Creek Tributary near Patzau	46.5033000	-92.2383000	219	1.4448	0.9293	1/6/1976	8/23/1978
WI	04024320	Little Balsam Creek near Foxboro	46.5092000	-92.2339000	149	15.703	1.9385	5/3/1977	7/7/1978
WI	04024430	Nemadji River near South Superior	46.6333000	-92.0939000	329	1.0905	1.7972	7/2/1973	8/20/1986
WI	04025500	Bois Brule River at Brule	46.5378000	-91.5953000	238	0.0674	2.3354	11/2/1972	10/15/2002
WI	04026005	Bois Brule River near Lake Superior	46.7056000	-91.6019000	43	0.0722	2.6101	11/2/1972	1/24/1978
WI	04026190	Sand River near Red Cliff	46.9000000	-90.9556000	61	7.0428	2.0223	9/11/1980	7/16/1984
WI	04026346	North Fish Creek near Benoit	46.5302220	-91.1476910	24	2.3606	1.5498	5/25/1989	10/9/1991
WI	04026347	Pine Creek at Moquah	46.5578000	-91.1050000	401	32.474	2.7749	8/26/1975	8/23/1978
WI	04026348	Pine Creek Tributary at Moquah	46.5742000	-91.0608000	64	1.1219	1.0809	11/18/1975	8/23/1978
WI	04026349	Pine Creek near Moquah	46.5492000	-91.0631000	913	2.4547	3.0164	8/26/1975	9/12/1978
WI	040263491	North Fish Creek near Moquah	46.5488330	-91.0621350	26	0.3975	2.7344	5/25/1989	10/15/2002
WI	04026350	North Fish Creek near Ashland	46.5785540	-90.9657440	21	0.9018	2.2373	5/25/1989	10/9/1991
WI	04026870	Alder Creek near Upson	46.3858000	-90.4083000	38	0.2725	0.9806	11/1/1972	7/18/1977
WI	04027000	Bad River near Odanah	46.4875000	-90.6958000	146	0.1693	1.8681	11/9/1972	4/7/2005
WI	04027496	White River near Sanborn	46.4925000	-90.9347000	94	0.2632	1.8893	5/20/1976	10/5/1977
WI	04027500	White River near Ashland	46.4972000	-90.9042000	574	5.7445	1.2174	8/22/1974	10/15/2003
WI	04027595	Bad River at Odanah	46.6103000	-90.6869000	58	0.0193	2.4136	2/1/1978	8/17/1983
MI	04040000	Ontonagon River near Rockland	46.7208000	-89.2069000	116	0.1089	1.9867	10/3/1975	8/29/1995
MI	04043004	Sturgeon River near Chassell	46.9744000	-88.5225000	59	0.021	2.3216	1/25/1978	7/17/1986
MI	04045500	Tahquamenon River near Paradise	46.5750000	-85.2694000	125	0.2294	1.1492	10/22/1974	7/15/1993
MI	04057004	Manistique River above Manistique	45.9717000	-86.2431000	94	0.0998	1.3494	10/17/1975	8/12/1986
MI	04059000	Escanaba River at Cornell	45.9086000	-87.2136000	145	0.1929	1.1792	12/6/1974	9/8/1994
MI	040590345	Escanaba River at Wells	45.7811110	-87.0675000	270	0.526	0.922	6/9/1988	4/26/1990
MI	04059500	Ford River near Hyde	45.7556000	-87.2014000	121	0.1034	1.6371	12/3/1974	4/29/1993
WI	04061000	Brule River near Florence	45.9585640	-88.2659670	34	0.6951	1.2349	11/13/1964	9/14/1967
MI	04062085	Peshekee River near Martins Landing	46.6097000	-88.0222000	9	0.2993	1.2904	4/13/1993	9/14/1993
WI	04063700	Popple River near Fence	45.7639000	-88.4639000	537	0.3233	1.185	10/17/1972	8/11/2005
WI	04066500	Pike River at Amberg	45.4999650	-88.0001150	32	0.6777	1.4999	11/13/2002	9/16/2004
WI	04067500	Menominee River near Mc Allister	45.3258000	-87.6633000	98	0.0049	1.9644	12/7/1977	10/14/2003

State	Gage number	Gage identification	Latitude	Longitude	Number of suspended-sediment samples	Load coefficient	Load exponent	First sample	Last sample
WI	04067651	Menominee River at Mouth at Marinette	45.0938890	-87.5936110	196	0.1226	1.3591	6/15/1988	5/2/1990
WI	04074548	Swamp Creek Below Rice Lake at Mole Lake	45.4794070	-88.9978920	18	0.2753	1.033	8/2/1977	8/30/1979
MI	04123910	Anderson Creek near Buckley	44.5122250	-85.6220120	21	0.2823	0.9467	6/19/1984	6/5/1986
MI	04125210	Silver Creek near Luther	44.1180650	-85.6847820	33	61.12	2.5366	10/13/1969	9/28/1970
MI	04125350	Poplar Creek near Hoxeyville	44.1711190	-85.7095060	31	16.951	4.0431	10/14/1969	9/8/1970
MI	04125450	Pine River near Dublin	44.1791740	-85.7611750	23	0.0404	3.1828	10/13/1969	6/3/1970
MI	04125510	Pine River near Wellston	44.2130620	-85.8964600	40	1.0963	2.0785	10/14/1969	9/14/1970
MI	04126970	Boardman River above Brown Bridge Road near Mayfield	44.6566700	-85.4367310	20	0.0787	2.5835	6/18/1984	6/4/1986
MI	04126991	Boardman River near Mayfield	44.6436140	-85.5092340	20	0.0907	1.3216	7/31/1984	6/4/1986
MI	04126997	East Creek at Green Road near Mayfield	44.6277800	-85.5042330	20	0.4884	1.8586	6/19/1984	6/4/1986
MI	04127008	Swainston Creek at Mayfield	44.6269470	-85.5325680	21	3.5719	2.4579	6/19/1984	6/4/1986
MI	04132052	Cheboygan River (Pond) at Lincoln Ave at Cheboygan	45.6339000	-84.4811000	104	0.1022	1.2482	10/10/1974	9/23/1986
MI	04132300	Hunt Creek at Hunt Creek Road near Lewiston	44.8692000	-84.1444000	55	5.198	2.815	10/1/1971	9/21/1972
MI	04135000	Thunder Bay River near Alpena	45.0942000	-83.4997000	93	0.1789	1.2461	10/4/1979	8/12/1993
MI	04135470	Au Sable River at Pollack Br near Grayling	44.6850150	-84.7455860	28	0.4206	1.6956	6/18/1991	6/11/1992
MI	04135475	Au Sable River at Old Dam Road near Grayling	44.6633000	-84.7406000	70	1.497	1.9012	6/18/1991	6/26/1992
MI	04137500	Au Sable River near Au Sable	44.4358000	-83.4411000	116	0.0879	1.3532	1/12/1978	8/16/1994
MI	04142000	Rifle River near Sterling	44.0725000	-84.0200000	131	0.1463	2.1974	10/11/1974	8/12/1992
MN	05124480	Kawishiwi River near Ely	47.9228000	-91.5350000	54	0.1892	1.1863	5/22/1979	5/15/2001
MN	05125550	Stony River near Babbitt	47.6932460	-91.7607090	21	0.2725	1.0911	11/3/1975	8/3/1977
MN	05216820	Initial Tailings Basin Outfall near Keewatin	47.3722000	-93.0328000	39	1.8214	1.0599	4/6/1983	3/25/1985
MN	05284305	Seguchie Creek at Holt Lake Outlet, near Garrison	46.2519040	-93.8274770	49	0.1279	0.7472	10/9/2003	9/25/2005
MN	05284310	Seguchie Creek above Mouth near Garrison	46.2535700	-93.8213660	64	0.1846	0.9301	10/9/2003	9/25/2005
WI	05331833	Namekagon River at Leonards	46.1717000	-91.3306000	32	0.1456	1.5627	4/23/1996	10/14/2002
WI	05331855	Namekagon River near Hayward	46.0516180	-91.4315670	27	0.0619	1.6603	10/20/1975	8/26/1985
WI	05332500	Namekagon River near Trego	45.9480010	-91.8882350	27	1.0255	0.3799	10/20/1975	8/26/1985
WI	05333500	St. Croix River near Danbury	46.0744000	-92.2472000	101	0.0158	1.9183	10/23/1975	10/16/2003
WI	05335031	Yellow River at Danbury	46.0121670	-92.3576940	22	0.2416	1.1024	10/23/1975	9/22/1998
WI	05335500	Clam River near Webster	45.8810600	-92.4879750	22	0.2359	1.7783	10/23/1975	9/24/1998
WI	05340390	Trade River near Trade River	45.5982920	-92.7674330	20	0.183	2.7488	4/1/1997	9/17/1999
WI	05357335	Bear River near Manitowish Waters	46.0489000	-89.9844000	96	0.1697	1.409	5/30/1991	9/29/1994
WI	05359500	South Fork Flambeau River near Phillips	45.7022000	-90.6161000	72	0.1034	1.384	10/3/1972	10/15/2003
WI	05367154	Sucker Creek at Loch Lomond Blvd near Birchwood	45.6249570	-91.5632200	94	0.7376	1.2131	10/11/2000	9/27/2001
WI	05367190	Hemlock Creek at County Trunk Hghwy F near Mikana	45.5741260	-91.5129410	73	0.3957	1.1422	10/11/2000	9/14/2001
WI	05393500	Spirit River at Spirit Falls	45.4491320	-89.9793110	31	0.2761	1.3905	10/2/1972	10/14/2002

Appendix B-v – Location of USGS gages with suspended-sediment data and transport rating relations in the Northern Central Hardwood Forest, Ecoregion 51.

State	Gage number	Gage identification	Latitude	Longitude	Number of suspended-sediment samples	Load coefficient	Load exponent	First sample	Last sample
WI	04071000	Oconto River near Gillett	44.865	-88.3	36	0.0359	1.8393	1/26/1972	10/13/2003
WI	04071795	Pensaukee River near Krakow	44.75249481	-88.27649103	36	2.1984	1.0983	4/6/1993	10/15/2002
WI	04071858	Pensaukee River near Pensaukee	44.81888889	-87.95444444	142	0.7736	1.3537	10/7/1972	10/15/2002
WI	04072233	Lancaster Brook at Shawano Ave at Horward	44.55804722	-88.10288133	82	12.327	1.2075	9/3/1997	8/8/2005
WI	04075365	Evergreen River below Evergreen Falls near Langlade	45.0658098	-88.6762169	43	1.7766	0.9988	10/3/2000	8/11/2005
WI	04077630	Red River at Morgan Road near Morgan	44.8980311	-88.8442729	226	0.7396	1.2284	11/4/1992	7/2/1998
WI	04078500	Embarrass River near Embarrass	44.7247017	-88.7362134	31	0.0758	1.9291	10/3/1972	10/16/2003
WI	04080798	Tomorrow River near Nelsonville	44.52441735	-89.3378918	36	0.7397	0.9464	4/9/1993	10/17/2002
WI	04085200	Kewaunee River near Kewaunee	44.45833125	-87.5564746	160	1.1101	1.4897	10/6/1972	10/15/2002
MI	04126520	Manistee River at Manistee	44.2505584	-86.319253	141	0.0837	1.4724	10/9/1974	4/22/1994
MI	04126546	Green Lake Inlet near Interlochen	44.6330568	-85.7820228	19	0.2184	1.1086	6/18/1984	6/3/1986
MI	04127250	Boardman River at Cass Road near Traverse City	44.6983349	-85.62062939	21	0.238	1.1875	6/19/1984	6/4/1986
MI	04127490	Boardman River at Traverse City	44.76222335	-85.62368729	21	0.124	1.3495	6/19/1984	6/4/1986
MI	04127498	Hospital Creek at Traverse City	44.76500106	-85.6331322	21	8.0144	2.2901	6/19/1984	6/5/1986
MI	04127520	Mitchell Creek at Traverse City	44.7477793	-85.5584065	21	2.399	1.521	6/19/1984	6/5/1986
MI	04127528	Acme Creek at HWY 31 at Acme	44.7752795	-85.4989607	20	1.5273	2.0822	6/19/1984	6/5/1986
MI	04127535	Yuba Creek near Acme	44.8244464	-85.4584048	21	2.0426	1.9722	6/18/1984	6/3/1986
MI	04127550	Tobeco Creek near Elk Rapids	44.85389106	-85.4320155	19	0.9339	1.4	6/18/1984	6/3/1986
MI	04127600	Battle Creek near Williamsburg	44.77278107	-85.3678426	21	1.4643	1.2786	6/18/1984	6/3/1986
MI	04127620	Williamsburg Creek at Ayers Road near Williamsburg	44.79500297	-85.3872888	21	0.0871	-0.7205	6/18/1984	6/3/1986
MN	05030150	Otter Trail River near Perham	46.64273722	-95.60448639	30	0.248	1.5042	4/1/1993	5/1/1996
MN	05030181	Otter Trail River at Little Pine Lake OTL near Perham	46.6266265	-95.5400403	8	0.1673	1.3732	10/18/1995	5/1/1996
MN	05030270	Toad River at Big Pine Lake Inlet near Perham	46.47746028	-95.51059639	24	0.9896	1.4068	3/14/1995	8/7/1996
MN	05030290	Otter Trail River at Big Pine Lake Outlet near Perham	46.59190444	-95.50392833	19	0.8178	0.7115	3/16/1995	4/30/1996
MN	05267000	Mississippi River near Royalton	45.8260765	-94.3552782	100	0.3201	1.2021	5/14/1975	4/3/1998
MN	05275000	Elk River near Big Lake	45.3338537	-93.6669098	23	0.6558	1.3433	8/26/1975	4/2/1997
MN	05276005	North Fork Crow River above Paynesville	45.3771864	-94.7836175	35	5.9134	0.821	4/2/1996	6/24/1998
MN	05288500	Mississippi River near Aonoka	45.1266318	-93.2968947	29	0.0154	1.7917	10/4/1983	8/7/1998
MN	05288705	Shingle Creek at Queen Avenue in Minneapolis	45.04996508	-93.3102274	121	2.2925	0.6922	3/13/1996	9/9/2005

State	Gage number	Gage identification	Latitude	Longitude	Number of suspended-sediment samples	Load coefficient	Load exponent	First sample	Last sample
MN	05330000	Minnesota River near Jordan	44.69301845	-93.641902	179	3.0138	1.3108	10/3/1974	9/3/1998
MN	05330902	Nine Mile Creek near James Circle at Bloomington	44.80718678	-93.3016129	55	2.7065	1.4761	3/11/1996	6/5/1998
MN	05331000	Mississippi River at St. Paul	44.93385459	-93.1060522	36	1.1059	1.2884	1/22/1974	8/1/1977
MN	05338500	Snake River near Pine City	45.84162199	-92.9335412	27	0.3068	1.1025	10/22/1975	4/3/1997
WI	05338955	Wood River at North Williams Road near Grantsburg	45.78522979	-92.6313137	21	0.6824	1.6379	2/23/1998	8/21/2002
WI	05340500	St. Croix River at St. Croix Falls	45.78522979	-92.63131371	166	0.0166	1.6957	11/11/1974	10/16/2003
WI	05341500	Apple River near Somerset	45.40690608	-92.6471513	18	0.0906	1.5257	8/26/1982	9/16/1999
WI	05364850	Duncan Creek Tributary near Tilden	45.1574665	-92.7165945	267	44.426	1.5761	12/31/1986	9/5/1989
WI	05367055	Chippewa River near Caryville	44.9888497	-91.447937	86	0.0268	1.6685	8/30/1976	9/22/1981
WI	05368000	Hay River at Wheeler	44.7605165	-91.6751665	80	0.1483	2.1129	10/12/1972	10/17/2002
WI	05381350	Levis Creek at Black River Falls	45.0477401	-91.9110104	16	0.4483	1.8519	10/12/1972	10/14/2003
WI	05394500	Prairie River near Merrill	44.31162806	-90.80653028	8	0.187	1.4133	3/14/1973	10/14/2002
WI	05397500	Eau Claire River at Kelly	45.23579915	-89.6498477	34	0.1337	1.6208	10/12/1972	10/17/2002
WI	05399500	Big Eau Pleine River at Stratford	44.91888889	-89.5519444	286	0.5867	1.2924	10/2/1972	10/17/2002
WI	05399550	Fenwood Creek at Bradley	44.8219098	-90.0795754	37	0.857	1.3402	4/26/1974	9/21/1980
WI	05399580	Fenwood Creek at Halder	44.8007989	-89.973462	40	0.7318	1.4659	4/26/1974	9/21/1980
WI	05399600	Big Eau Pleine River near Knowlton	44.7863551	-89.8617927	466	0.4764	1.0351	5/9/1974	3/23/1981
WI	05400650	Little Plover River at Plover	44.73107769	-89.75956783	32	0.3983	1.1019	10/16/1972	10/17/2002
WI	05401050	Tenmile Creek near Nekoosa	44.4738579	-89.5290065	62	0.588	2.0832	11/10/1972	10/17/2002
WI	05401535	Big Roche A Cri Creek near Adams	44.26246676	-89.8104021	24	0.441	1.2927	11/10/1972	5/19/1975
WI	05402000	Yellow River at Babcock	44.09746923	-89.77651387	8	0.5101	1.255	3/8/1973	10/16/2002
WI	05403500	Lemonweir River at New Lisbon	44.30218536	-90.1220761	175	0.9408	0.8809	10/12/1972	10/14/2003
WI	05403630	Hulbert Creek near Wisconsin Dells	43.8796913	-90.16124	41	1.7669	1.4292	11/16/1972	8/18/1977

Appendix C-i – Rapid Geomorphic Assessments carried out at USGS gages with sufficient suspended-sediment data in the Northern Glaciated Plains, Ecoregion 46.

State	Gage number	Gage identification	Bed material	Bed or bank protection	Incision	Constriction	Streambank erosion		Streambank instability		Woody vegetative cover		Bank accretion		Stage of channel evolution	Channel stability index
							Left	Right	Left	Right	Left	Right	Left	Right		
ND	05058700	Sheyenne River at Lisbon	Silt/Clay	1 Bank	0-10%	11-25%	Fluvial	Fluvial	11-25%	11-25%	0-10%	0-10%	0-10%	0-10%	II	23
ND	05064900	Beaver Creek near Finley	Boulder/Cobble	Yes	76-100%	0-10%	None	None	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	VI	10.5
ND	05099380	Pembina River near Vang	Silt/Clay	No	0-10%	0-10%	Mass Wasting	Mass Wasting	26-50%	76-100%	0-10%	11-25%	76-100%	11-25%	V	24
ND	05099400	Little South Pembina River near Walhalla	Gravel/Cobble	No	26-50%	0-10%	None	Fluvial	0-10%	11-25%	51-75%	0-10%	76-100%	0-10%	V	13.5
ND	05114000	Souris River near Sherwood	Silt/Clay	No	11-25%	0-10%	Mass Wasting	Mass Wasting	51-75%	51-75%	0-10%	0-10%	0-10%	0-10%	IV	27
ND	05116000	Souris River near Foxholm	Silt/Clay	No	51-75%	0-10%	None	None	0-10%	0-10%	0-10%	26-50%	0-10%	0-10%	I	13
ND	05120000	Souris River near Verendrye	Silt/Clay	No	11-25%	0-10%	None	None	0-10%	0-10%	26-50%	11-25%	0-10%	0-10%	VI	16
ND	05122000	Souris River near Bantry	Silt/Clay	No	26-50%	0-10%	Fluvial	Mass Wasting	26-50%	51-75%	26-50%	11-25%	26-50%	11-25%	V	20.5
ND	05123400	Willow Creek near Willow City	Sand/silt	No	76-100%	0-10%	Fluvial	None	0-10%	0-10%	26-50%	51-75%	0-10%	0-10%	VI	12.5
ND	05123500	Stone Creek near Kramer	Sand	No	51-75%	0-10%	Mass Wasting	Fluvial	51-75%	0-10%	26-50%	76-100%	0-10%	0-10%	I	14.5
ND	05123760	Deep River Below Cut Bank Creek near Upham	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ND	05123900	Boundary Creek near Landa	Sand/Gravel	No	51-75%	0-10%	Fluvial	Fluvial	0-10%	0-10%	76-100%	76-100%	11-25%	0-10%	VI	11.5
ND	05124000	Souris River near Westhope	Silt/Clay	No	76-100%	0-10%	Fluvial	Fluvial	26-50%	26-50%	76-100%	76-100%	0-10%	0-10%	VI	14.5
SD	05291000	Whetstone River near Big Stone City	Boulder/Cobble	No	26-50%	0-10%	None	Mass Wasting	0-10%	51-75%	51-75%	26-50%	51-75%	0-10%	V	14.5
SD	05292810	Labolt Impoundment Inlet at Labolt	Gravel	No	11-25%	0-10%	None	Fluvial	0-10%	0-10%	76-100%	51-75%	76-100%	0-10%	VI	11
MN	05293000	Yellow Bank River near Odessa	Sand	No	11-25%	0-10%	None	Mass Wasting	0-10%	51-75%	26-50%	26-50%	76-100%	0-10%	V	17.5
SD	05299670	West Branch Lac Qui Parle River near Gary	Gravel	No	11-25%	0-10%	None	Mass Wasting	0-10%	51-75%	0-10%	26-50%	76-100%	0-10%	V	17.5
MN	05299750	Florida Creek near Burr	Gravel	No	26-50%	0-10%	None	Fluvial	0-10%	26-50%	76-100%	26-50%	76-100%	26-50%	VI	10.5
MN	05304500	Chippewa River near Milan	Sand/Gravel	No	11-25%	0-10%	None	Mass Wasting	26-50%	76-100%	51-75%	11-25%	51-75%	0-10%	V	19
MN	05311000	Minnesota River at Montevideo	Sand	No	11-25%	0-10%	None	None	11-25%	0-10%	26-50%	26-50%	51-75%	51-75%	VI	12
MN	05311310	Dillon-Sylte Impoundment Inlet near Porter	Gravel	No	11-25%	0-10%	None	Mass Wasting	0-10%	76-100%	51-75%	0-10%	76-100%	0-10%	V	17.5
MN	05311320	Dillon-Sylte Impoundment Outlet near Porter	-	-	-	-	-	-	-	-	-	-	-	-	II	-
ND	06467600	James River near Manfred	Sand	Yes	51-75%	0-10%	None	Fluvial	0-10%	11-25%	0-10%	0-10%	76-100%	76-100%	VI	11
ND	06468170	James River near Grace City	Gravel	1 Bank	51-75%	11-25%	None	Mass Wasting	0-10%	51-75%	0-10%	0-10%	76-100%	11-25%	VI	16.5
ND	06468250	James River above Arrowwood Lake near Kensal	Sand	Yes	76-100%	0-10%	None	Fluvial	0-10%	11-25%	0-10%	0-10%	76-100%	0-10%	VI	12
ND	06468500	James River near Pingree	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ND	06470000	James River at Jamestown	Sand	No	11-25%	0-10%	None	Mass Wasting	0-10%	76-100%	0-10%	11-25%	51-75%	0-10%	V	20
ND	06470500	James River at Lamoure	Silt/Clay	Yes	51-75%	11-25%	None	None	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	II	15
ND	06470830	James River at Oakes	Silt/Clay	No	76-100%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	76-100%	76-100%	I	5
ND	06470875	James River at Dakota Lake Dam near Ludden	Silt/Clay	No	76-100%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	76-100%	76-100%	I	5
SD	06470980	James River near Hecla	Sand	No	76-100%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	76-100%	76-100%	I	4
SD	06471000	James River at Columbia	Silt/Clay	No	26-50%	0-10%	None	Mass Wasting	0-10%	76-100%	51-75%	0-10%	76-100%	0-10%	V	18.5
SD	06473000	James River at Ashton	Silt/Clay	No	51-75%	0-10%	None	Mass Wasting	0-10%	76-100%	51-75%	0-10%	76-100%	0-10%	V	17.5
SD	06478500	James River near Scotland	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SD	06479529	Stray Horse Creek near Castlewood	Sand	No	76-100%	0-10%	None	None	0-10%	11-25%	76-100%	76-100%	76-100%	76-100%	VI	6
SD	06479640	Hidewood Creek near Estelline	Sand	No	76-100%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	76-100%	76-100%	VI	5.5
SD	06480000	Big Sioux River near Brookings	Sand	No	11-25%	0-10%	None	Mass Wasting	0-10%	76-100%	26-50%	11-25%	51-75%	11-25%	V	18.5
SD	06481500	Skunk Creek at Sioux Falls	Gravel	2 Banks	26-50%	0-10%	None	None	26-50%	26-50%	11-25%	26-50%	11-25%	0-10%	V	18

Appendix C-ii – Rapid Geomorphic Assessments carried out at USGS gages with sufficient suspended-sediment data in the Western Corn Belt Plains, Ecoregion 47.

State	Gage number	Gage identification	Bed material	Bed or bank protection	Incision	Constriction	Streambank erosion		Streambank instability		Woody vegetative cover		Bank accretion		Stage of channel evolution	Channel stability index
							Left	Right	Left	Right	Left	Right	Left	Right		
MN	05316500	Redwood River near Redwood Falls	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MN	05319500	Watonwan River near Garden City	Sand	No	51-75%	0-10%	Fluvial	Fluvial	26-50%	11-25%	26-50%	51-75%	76-100%	11-25%	V	14.5
MN	05320270	Little Cobb River near Beauford	Sand	No	51-75%	11-25%	Fluvial	None	11-25%	0-10%	0-10%	51-75%	0-10%	76-100%	V	15
MN	05320300	Cobb River Tributary near Mapleton	Sand	Yes	51-75%	26-50%	None	None	0-10%	0-10%	76-100%	11-25%	76-100%	76-100%	II	8.5
MN	05320500	Le Sueur River near Rapidan	Sand/Gravel	No	26-50%	0-10%	Fluvial	Fluvial	0-10%	26-50%	0-10%	0-10%	76-100%	76-100%	VI	14
MN	05322000	Minnesota River at Mankato	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MN	05325000	Minnesota River at Mankato	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IA	05418500	Maquoketa River near Maquoketa	Sand	No	51-75%	0-10%	None	None	0-10%	0-10%	51-75%	51-75%	76-100%	76-100%	VI	7.5
IA	05420680	Wapsipinicon River near Tripoli	Cobble/gravel	No	76-100%	0-10%	Fluvial	Fluvial	26-50%	26-50%	76-100%	76-100%	26-50%	26-50%	V	13
IA	05422000	Wapsipinicon River near De Witt	Sand	2 Banks	11-25%	0-10%	None	None	0-10%	11-25%	26-50%	26-50%	76-100%	76-100%	VI	13
IA	05449500	Iowa River near Rowan	Sand	No	26-50%	0-10%	None	None	0-10%	0-10%	26-50%	26-50%	76-100%	76-100%	VI	9.5
IA	05451210	South Fork Iowa River Ne Of New Providence	Sand/Gravel	No	0-10%	0-10%	None	Fluvial	0-10%	51-75%	76-100%	0-10%	76-100%	11-25%	VI	15
IA	05451500	Iowa River at Marshalltown	Sand	No	11-25%	0-10%	None	Fluvial	0-10%	26-50%	26-50%	26-50%	76-100%	76-100%	V	14
IA	05453100	Iowa River at Marengo	Sand	No	11-25%	0-10%	None	Fluvial	0-10%	11-25%	26-50%	51-75%	76-100%	26-50%	VI	12.5
IA	05454500	Iowa River at Iowa City	Sand	2 Banks	76-100%	0-10%	None	None	0-10%	0-10%	11-25%	26-50%	76-100%	76-100%	VI	10
IA	05455100	Old Mans Creek near Iowa City	Sand/Gravel	No	51-75%	0-10%	None	None	0-10%	0-10%	51-75%	26-50%	76-100%	76-100%	VI	7.5
MN	05457000	Cedar River near Austin	Sand/Gravel	No	76-100%	0-10%	Fluvial	None	0-10%	0-10%	76-100%	76-100%	76-100%	76-100%	VI	6
IA	05461390	Flood Creek near Powersville	Sand	No	76-100%	0-10%	None	None	0-10%	0-10%	51-75%	76-100%	76-100%	76-100%	VI	6
IA	05463050	Cedar River at Cedar Falls	Sand	2 Banks	26-50%	51-75%	None	None	0-10%	0-10%	0-10%	0-10%	26-50%	0-10%	II	19
IA	05464220	Wolf Creek near Dysart	Sand	No	51-75%	0-10%	None	None	0-10%	0-10%	11-25%	11-25%	51-75%	51-75%	VI	10.5
IA	05471050	South Skunk River at Colfax	Sand	No	51-75%	0-10%	None	None	0-10%	0-10%	76-100%	26-50%	76-100%	51-75%	VI	8
IA	05481650	Des Moines River near Saylorville	Sand	No	0-10%	0-10%	Mass Wasting	Mass Wasting	51-75%	51-75%	26-50%	26-50%	51-75%	51-75%	V	21
IA	05483450	Middle Raccoon River near Bayard	Sand	No	0-10%	0-10%	Fluvial	Fluvial	11-25%	11-25%	26-50%	26-50%	76-100%	76-100%	VI	14.5
IA	05483600	Middle Raccoon River at Panora	Sand/silt	No	51-75%	11-25%	None	None	0-10%	0-10%	51-75%	51-75%	76-100%	76-100%	II	8.5
IA	05484500	Raccoon River at Van Meter	Sand	No	26-50%	0-10%	Fluvial	Fluvial	0-10%	11-25%	11-25%	11-25%	76-100%	76-100%	VI	13
IA	06485500	Big Sioux River at Akron	Sand	No	51-75%	0-10%	Mass Wasting	Fluvial	76-100%	11-25%	26-50%	51-75%	11-25%	26-50%	V	17.5
NE	06486000	Missouri River at Sioux City	Sand	2 Banks	51-75%	11-25%	None	None	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	II	17
NE	06610000	Missouri River at Omaha	Sand	1 Bank	76-100%	0-10%	Mass Wasting	None	11-25%	0-10%	26-50%	76-100%	51-75%	76-100%	VI	10.5
NE	06796000	Platte River at North Bend	Sand	No	76-100%	0-10%	Fluvial	Fluvial	0-10%	0-10%	76-100%	76-100%	0-10%	0-10%	VI	11.5
NE	06798500	Elkhorn River at Neligh	Sand	1 Bank	26-50%	0-10%	None	Fluvial	0-10%	0-10%	26-50%	26-50%	0-10%	0-10%	V	17
NE	06799000	Elkhorn River at Norfolk Ne	Sand	1 Bank	26-50%	0-10%	Fluvial	Fluvial	0-10%	0-10%	51-75%	51-75%	0-10%	0-10%	VI	15.5
NE	06799450	Logan Creek at Pender Ne	Sand	No	11-25%	0-10%	Fluvial	Fluvial	11-25%	11-25%	26-50%	26-50%	11-25%	11-25%	V	18
NE	06800000	Maple Creek near Nickerson	Sand	No	26-50%	0-10%	None	Mass Wasting	0-10%	51-75%	51-75%	0-10%	76-100%	11-25%	V	16.5
NE	06800500	Elkhorn River at Waterloo	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NE	06803555	Salt Creek at Greenwood	Sand	No	11-25%	0-10%	Mass Wasting	Mass Wasting	26-50%	51-75%	76-100%	26-50%	26-50%	51-75%	V	19
NE	06805500	Platte River at Louisville Ne	Sand	No	76-100%	76-100%	Mass Wasting	Mass Wasting	51-75%	51-75%	11-25%	11-25%	0-10%	0-10%	V	25
NE	06807000	Missouri River at Nebraska City	Sand	No	51-75%	0-10%	Fluvial	Fluvial	0-10%	0-10%	76-100%	51-75%	76-100%	51-75%	VI	9.5
IA	06810000	Nishnabotna River Above Hamburg	Sand	No	11-25%	0-10%	Fluvial	Fluvial	0-10%	0-10%	51-75%	51-75%	0-10%	0-10%	VI	15.5
NE	06810900	Brownell Creek subwtaershed 1A near Syracuse	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NE	06811000	Borwnell Creek Subwatershed 1 near Syracuse	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KS	06815274	Walnut Creek near Fairview	Sand	No	11-25%	0-10%	Fluvial	Mass Wasting	0-10%	51-75%	51-75%	11-25%	26-50%	0-10%	V	19.5
KS	06815280	Mulberry Creek near Fairview	Sand	Yes	26-50%	0-10%	Mass Wasting	None	76-100%	0-10%	11-25%	26-50%	0-10%	76-100%	V	16.5
KS	06815288	Walnut Creek near Hamlin	Sand/silt	No	0-10%	0-10%	Mass Wasting	Mass Wasting	51-75%	51-75%	11-25%	11-25%	0-10%	0-10%	IV	26.5
KS	06815290	Terrapin Creek at Hamlin	Silt/Clay	No	0-10%	0-10%	Mass Wasting	Mass Wasting	51-75%	51-75%	0-10%	0-10%	0-10%	0-10%	IV	28
KS	06815300	Walnut Creek at Reserve	Sand	No	26-50%	0-10%	Fluvial	Mass Wasting	0-10%	26-50%	26-50%	26-50%	11-25%	0-10%	VI	17
KS	06815570	Wolf River 3 Miles Sw Of Hiawatha	Silt/Clay	No	0-10%	0-10%	None	Mass Wasting	0-10%	76-100%	0-10%	0-10%	11-25%	0-10%	V	23.5

State	Gage number	Gage identification	Bed material	Bed or bank protection	Incision	Constriction	Streambank erosion		Streambank instability		Woody vegetative cover		Bank accretion		Stage of channel evolution	Channel stability index
							Left	Right	Left	Right	Left	Right	Left	Right		
KS	06815578	Wolf River at Hiawatha	Sand	No	11-25%	0-10%	Mass Wasting	Mass Wasting	76-100%	26-50%	11-25%	26-50%	0-10%	26-50%	V	22.5
KS	06815700	Buttermilk Creek near Willis	Sand	No	0-10%	0-10%	Mass Wasting	Mass Wasting	76-100%	76-100%	26-50%	26-50%	0-10%	11-25%	IV	25.5
KS	06815800	Wolf River at Leona	Sand	No	11-25%	0-10%	None	Mass Wasting	0-10%	76-100%	0-10%	0-10%	76-100%	0-10%	V	20
KS	06815880	Wolf River near Sparks	Sand	No	11-25%	0-10%	Fluvial	Fluvial	0-10%	0-10%	26-50%	26-50%	0-10%	0-10%	V	18
IA	06817000	Nodaway River at Clarinda	Sand	No	26-50%	0-10%	Mass Wasting	Mass Wasting	11-25%	11-25%	26-50%	26-50%	26-50%	26-50%	V	18
MO	06818000	Missouri River at St. Joseph	Sand	1 Bank	51-75%	0-10%	Fluvial	None	0-10%	0-10%	0-10%	26-50%	26-50%	0-10%	VI	14.5
MO	06821190	Platte River at Sharps Station	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NE	06882000	Big Blue River at Barneston Nebr	Gravel	No	11-25%	0-10%	Mass Wasting	Mass Wasting	11-25%	11-25%	51-75%	76-100%	11-25%	11-25%	V	17.5
KS	06885500	Black Vermillion River near Frankfort	Silt/Clay	No	11-25%	0-10%	None	None	0-10%	0-10%	0-10%	0-10%	76-100%	76-100%	VI	13.5
KS	06889100	Soldier Creek near Goff	Sand	No	26-50%	0-10%	Fluvial	Fluvial	0-10%	0-10%	51-75%	51-75%	11-25%	51-75%	VI	12.5
KS	06889120	Soldier Creek near Bancroft	Sand	No	76-100%	0-10%	None	Fluvial	0-10%	0-10%	26-50%	0-10%	76-100%	0-10%	V	13
KS	06889140	Soldier Creek near Soldier	Bedrock	No	11-25%	0-10%	Fluvial	Fluvial	0-10%	0-10%	11-25%	11-25%	26-50%	26-50%	VI	12.5
KS	06889160	Soldier Creek near Circleville	Sand/Gravel	Yes	11-25%	0-10%	None	Mass Wasting	0-10%	76-100%	11-25%	76-100%	0-10%	76-100%	VI	14.5
KS	06890000	L Delaware River near Horton	Sand	No	11-25%	0-10%	Mass Wasting	Mass Wasting	26-50%	26-50%	51-75%	26-50%	0-10%	0-10%	V	21.5
KS	06890096	L Grasshopper Creek at Muscotah	Sand	No	11-25%	0-10%	None	Mass Wasting	0-10%	76-100%	26-50%	0-10%	76-100%	0-10%	V	19
KS	06890100	Delaware River near Muscotah	Sand	No	11-25%	0-10%	Mass Wasting	Mass Wasting	26-50%	51-75%	26-50%	11-25%	76-100%	0-10%	V	21
MO	06893000	Missouri River at Kansas City	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Appendix C-iii – Rapid Geomorphic Assessments carried out at USGS gages with sufficient suspended-sediment data in the Lake Agassiz Plain, Ecoregion 48.

State	Gage number	Gage identification	Bed material	Bed or bank protection	Incision	Constriction	Streambank erosion		Streambank instability		Woody vegetative cover		Bank accretion		Stage of channel evolution	Channel stability index
							Left	Right	Left	Right	Left	Right	Left	Right		
ND	05051522	Red River of the North at Hickson	Silt/Clay	No	11-25%	0-10%	None	Mass Wasting	11-25%	51-75%	0-10%	0-10%	11-25%	0-10%	III	21.5
ND	05053000	Wild Rice River near Abercrombie	Silt/Clay	No	0-10%	0-10%	None	Mass Wasting	11-25%	76-100%	26-50%	0-10%	26-50%	0-10%	V	22.5
ND	05054020	Red River of the North below Fargo	Silt/Clay	No	0-10%	0-10%	Mass Wasting	Mass Wasting	76-100%	76-100%	26-50%	26-50%	0-10%	0-10%	IV	27
ND	05059000	Sheyenne River near Kindred	Silt/Clay	Yes	0-10%	0-10%	Mass Wasting	Mass Wasting	76-100%	76-100%	0-10%	11-25%	0-10%	0-10%	II	24.5
MN	05062500	Wild Rice River at Twin Valley	Sand/Gravel	No	26-50%	11-25%	None	Mass Wasting	0-10%	76-100%	0-10%	0-10%	76-100%	0-10%	V	19.5
MN	05064000	Wild Rice River at Hendrum	Silt/Clay	No	11-25%	0-10%	Mass Wasting	Mass Wasting	76-100%	76-100%	51-75%	26-50%	0-10%	0-10%	IV	25.5
MN	05064500	Red River of the North at Halstad	Silt/Clay	No	0-10%	0-10%	Mass Wasting	Fluvial	51-75%	11-25%	26-50%	11-25%	0-10%	0-10%	V	23.5
MN	05079000	Red Lake River at Crookston	Sand	2 Banks	11-25%	11-25%	Mass Wasting	None	51-75%	0-10%	26-50%	11-25%	0-10%	51-75%	V	21.5
ND	05082625	Turtle River at Turtle River State Park near Arvilla	Sand	No	51-75%	0-10%	None	None	0-10%	11-25%	11-25%	0-10%	76-100%	11-25%	V	13.5
MN	05083500	Red River of the North at Olso	Silt/Clay	1 Bank	11-25%	0-10%	None	None	11-25%	11-25%	11-25%	11-25%	51-75%	51-75%	VI	15.5
MN	05085900	Snake River above Alvarado	Silt/Clay	No	51-75%	0-10%	None	None	11-25%	0-10%	26-50%	51-75%	76-100%	76-100%	VI	9.5
ND	05099600	Pembina River at Walhalla	Sand/Gravel	No	11-25%	0-10%	None	Mass Wasting	0-10%	76-100%	26-50%	0-10%	76-100%	0-10%	V	18.5
ND	05102490	Red River of the North at Pembina	Silt/Clay	No	11-25%	0-10%	Mass Wasting	Mass Wasting	76-100%	51-75%	51-75%	51-75%	51-75%	51-75%	V	20.5
MN	05061000	Buffalo River near Hawley	Boulder/Cobble	No	51-75%	0-10%	Fluvial	Fluvial	11-25%	11-25%	76-100%	76-100%	0-10%	0-10%	I	10
MN	05061500	South Branch Buffalo River at Sabin	Silt/Clay	No	76-100%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	76-100%	76-100%	VI	6.5
MN	05062000	Buffalo River near Dilworth	Silt/Clay	No	26-50%	0-10%	Mass Wasting	Mass Wasting	51-75%	51-75%	11-25%	11-25%	11-25%	11-25%	IV	24
MN	05087500	Middle River at Argyle	Silt/Clay	No	26-50%	0-10%	None	Mass Wasting	0-10%	76-100%	26-50%	0-10%	51-75%	0-10%	V	19.5

Appendix C-iv – Rapid Geomorphic Assessments carried out at USGS gages with sufficient suspended-sediment data in the Northern Lakes and Forest, Ecoregion 50.

State	Gage number	Gage identification	Bed material	Bed or bank protection	Incision	Constriction	Streambank erosion		Streambank instability		Woody vegetative cover		Bank accretion		Stage of channel evolution	Channel stability index
							Left	Right	Left	Right	Left	Right	Left	Right		
MI	04001000	Washington Creek at Windingo	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MN	04014500	Baptism River near Beaver Bay	Bedrock	Yes	51-75%	0-10%	None	None	0-10%	0-10%	11-25%	26-50%	26-50%	76-100%	VI	6
MN	04024000	St. Louis River at Scanlon	Bedrock	Yes	76-100%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	76-100%	76-100%	VI	1.5
WI	04024314	Little Balsam Creek at Patzau	Gravel	No	0-10%	0-10%	None	Fluvial	0-10%	11-25%	76-100%	76-100%	76-100%	0-10%	VI	12
WI	04024315	Little Balsam Creek near Patzau	Gravel	No	0-10%	0-10%	None	Fluvial	0-10%	11-25%	76-100%	51-75%	76-100%	11-25%	VI	12
WI	04024318	Little Balsam Creek Tributary near Patzau	Sand	No	11-25%	0-10%	Fluvial	Mass Wasting	11-25%	51-75%	0-10%	0-10%	0-10%	26-50%	V	22
WI	04024320	Little Balsam Creek near Foxboro	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WI	04024430	Nemadji River near South Superior	Sand	No	26-50%	0-10%	None	Mass Wasting	0-10%	51-75%	26-50%	11-25%	76-100%	11-25%	V	16.5
WI	04025500	Bois Brule River at Brule	Cobble/gravel	No	76-100%	0-10%	None	None	0-10%	11-25%	76-100%	51-75%	11-25%	11-25%	I	6.5
WI	04026005	Bois Brule River near Lake Superior	Boulder/Cobble	No	76-100%	0-10%	Fluvial	None	0-10%	0-10%	76-100%	26-50%	0-10%	76-100%	VI	7.5
WI	04026190	Sand River near Red Cliff	Sand	No	76-100%	11-25%	None	Mass Wasting	0-10%	51-75%	76-100%	26-50%	11-25%	76-100%	V	14
WI	04026346	North Fish Creek near Benoit	Gravel	Yes	51-75%	11-25%	Fluvial	None	0-10%	0-10%	51-75%	51-75%	26-50%	26-50%	VI	9.5
WI	04026347	Pine Creek at Moquah	Sand	No	76-100%	0-10%	Fluvial	Fluvial	0-10%	0-10%	76-100%	76-100%	0-10%	0-10%	I	10
WI	04026348	Pine Creek Tributary at Moquah	Sand	No	76-100%	0-10%	None	None	0-10%	0-10%	0-10%	0-10%	76-100%	76-100%	VI	9.5
WI	04026349	Pine Creek near Moquah	Sand	2 Banks	76-100%	0-10%	None	None	0-10%	0-10%	51-75%	76-100%	0-10%	0-10%	I	10.5
WI	040263491	North Fish Creek near Moquah	-	-	-	-	-	-	-	-	-	-	-	-	II	1
WI	04026350	North Fish Creek near Ashland	Sand	No	76-100%	0-10%	None	None	11-25%	0-10%	26-50%	76-100%	76-100%	76-100%	VI	7
WI	04026870	Alder Creek near Upson	Sand	No	76-100%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	0-10%	0-10%	I	8
WI	04027000	Bad River near Odanah	-	-	-	-	-	-	-	-	-	-	-	-	II	-
WI	04027496	White River near Sanborn	-	-	-	-	-	-	-	-	-	-	-	-	II	-
WI	04027500	White River near Ashland	-	-	-	-	-	-	-	-	-	-	-	-	II	-
WI	04027595	Bad River at Odanah	Sand	No	76-100%	0-10%	None	None	0-10%	0-10%	51-75%	51-75%	0-10%	0-10%	I	6
MI	04040000	Ontonagon River near Rockland	Sand	No	51-75%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	76-100%	76-100%	VI	6.5
MI	04043004	Sturgeon River near Chassell	Sand	No	26-50%	0-10%	Mass Wasting	None	76-100%	11-25%	26-50%	11-25%	26-50%	51-75%	V	17.5
MI	04045500	Tahquamenon River near Paradise	Sand	No	76-100%	0-10%	None	Mass Wasting	0-10%	51-75%	76-100%	76-100%	76-100%	0-10%	V	12.5
MI	04057004	Manistique River above Manistique	-	-	-	-	-	-	-	-	-	-	-	-	II	1
MI	04059000	Escanaba River at Cornell	Bedrock	No	76-100%	0-10%	None	None	0-10%	26-50%	76-100%	76-100%	51-75%	51-75%	VI	4.5
MI	040590345	Escanaba River at Wells	Sand	No	76-100%	0-10%	None	None	0-10%	0-10%	26-50%	76-100%	0-10%	0-10%	I	9
MI	04059500	Ford River near Hyde	Bedrock	No	76-100%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	0-10%	0-10%	I	5
WI	04061000	Brule River near Florence	Boulder/Cobble	No	76-100%	0-10%	None	None	0-10%	0-10%	11-25%	11-25%	0-10%	0-10%	I	9
WI	04063700	Popple River near Fence	Gravel	No	76-100%	26-50%	None	None	0-10%	0-10%	11-25%	76-100%	0-10%	0-10%	I	10.5
WI	04066500	Pike River at Amberg	Sand	No	76-100%	0-10%	Mass Wasting	None	76-100%	0-10%	76-100%	76-100%	0-10%	76-100%	V	13
WI	04067500	Menominee River near Mc Allister	Boulder/Cobble	No	76-100%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	0-10%	0-10%	I	6
WI	04067651	Menominee River at Mouth at Marinette	-	-	-	-	-	-	-	-	-	-	-	-	II	-
WI	04074548	Swamp Creek Below Rice Lake at Mole Lake	Gravel	No	76-100%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	0-10%	0-10%	I	7
MI	04123910	Anderson Creek near Buckley	Sand	No	76-100%	0-10%	None	None	0-10%	26-50%	76-100%	76-100%	76-100%	76-100%	VI	6.5
MI	04125210	Silver Creek near Luther	Gravel	No	76-100%	0-10%	None	None	0-10%	0-10%	76-100%	51-75%	76-100%	51-75%	VI	5.5
MI	04125350	Poplar Creek near Hoxeyville	Sand/Gravel	Yes	76-100%	0-10%	None	None	0-10%	0-10%	11-25%	11-25%	76-100%	76-100%	I	5.5
MI	04125450	Pine River near Dublin	Sand	No	76-100%	0-10%	None	None	11-25%	0-10%	76-100%	76-100%	76-100%	76-100%	VI	6
MI	04125510	Pine River near Wellston	Sand	No	76-100%	0-10%	None	None	0-10%	0-10%	26-50%	26-50%	76-100%	76-100%	I	6
MI	04126970	Boardman River above Brown Bridge Road near	Gravel	No	76-100%	0-10%	None	None	11-25%	0-10%	76-100%	51-75%	26-50%	76-100%	VI	6.5

State	Gage number	Gage identification	Bed material	Bed or bank protection	Incision	Constriction	Streambank erosion		Streambank instability		Woody vegetative cover		Bank accretion		Stage of channel evolution	Channel stability index
							Left	Right	Left	Right	Left	Right	Left	Right		
		Mayfield														
MI	04126991	Boardman River near Mayfield	-	-	-	-	-	-	-	-	-	-	-	-	II	-
MI	04126997	East Creek at Green Road near Mayfield	Sand	No	76-100%	0-10%	Fluvial	None	0-10%	0-10%	76-100%	76-100%	0-10%	76-100%	VI	8.5
MI	04127008	Swainston Creek at Mayfield	Gravel	No	76-100%	0-10%	None	None	0-10%	0-10%	76-100%	51-75%	76-100%	76-100%	I	3.5
MI	04132052	Cheboygan River (Pond) at Lincoln Ave at Cheboygan	-	-	-	-	-	-	-	-	-	-	-	-	II	-
MI	04132300	Hunt Creek at Hunt Creek Road near Lewiston	Sand	No	76-100%	0-10%	None	Mass Wasting	11-25%	51-75%	76-100%	11-25%	51-75%	0-10%	V	15
MI	04135000	Thunder Bay River near Alpena	-	-	-	-	-	-	-	-	-	-	-	-	II	-
MI	04135470	Au Sable River at Pollack Br near Grayling	Sand	No	76-100%	0-10%	None	None	0-10%	0-10%	26-50%	26-50%	0-10%	0-10%	I	10
MI	04135475	Au Sable River at Old Dam Road near Grayling	-	-	-	-	-	-	-	-	-	-	-	-	II	-
MI	04137500	Au Sable River near Au Sable	Gravel	No	26-50%	0-10%	Mass Wasting	None	0-10%	26-50%	76-100%	76-100%	26-50%	76-100%	V	12
MI	04142000	Rifle River near Sterling	Sand	2 Banks	51-75%	0-10%	Mass Wasting	None	51-75%	11-25%	51-75%	26-50%	11-25%	51-75%	VI	17
MN	05124480	Kawishiwi River near Ely	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MN	05125550	Stony River near Babbitt	Boulder/Cobble	1 Bank	76-100%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	26-50%	26-50%	I	6
MN	05216820	Initial Tailings Basin Outfall near Keewatin	-	-	-	-	-	-	-	-	-	-	-	-	II	1
MN	05284305	Seguchie Creek at Holt Lake Outlet, near Garrison	-	-	-	-	-	-	-	-	-	-	-	-	II	1
MN	05284310	Seguchie Creek above Mouth near Garrison	Sand	No	76-100%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	76-100%	76-100%	VI	5.5
WI	05331833	Namekagon River at Leonards	Boulder/Cobble	No	26-50%	0-10%	Fluvial	None	0-10%	0-10%	76-100%	76-100%	11-25%	0-10%	I	8.5
WI	05331855	Namekagon River near Hayward	Boulder/Cobble	No	76-100%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	51-75%	51-75%	I	3
WI	05332500	Namekagon River near Trego	Bedrock	-	-	-	-	-	-	-	-	-	-	-	II	1
WI	05333500	St. Croix River near Danbury	Gravel	No	51-75%	0-10%	None	None	11-25%	0-10%	76-100%	76-100%	51-75%	51-75%	VI	7
WI	05335031	Yellow River at Danbury	Sand	No	51-75%	0-10%	None	None	11-25%	0-10%	76-100%	76-100%	51-75%	51-75%	VI	8
WI	05335500	Clam River near Webster	Sand	No	76-100%	0-10%	None	Fluvial	0-10%	26-50%	76-100%	26-50%	51-75%	11-25%	VI	10.5
WI	05340390	Trade River near Trade River	Sand/Gravel	No	26-50%	0-10%	Fluvial	Fluvial	26-50%	11-25%	51-75%	51-75%	11-25%	26-50%	III	14.5
WI	05357335	Bear River near Manitowish Waters	Silt/Clay	No	76-100%	0-10%	None	None	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	I	13
WI	05359500	South Fork Flambeau River near Phillips	Gravel	No	76-100%	0-10%	None	None	0-10%	0-10%	76-100%	26-50%	0-10%	11-25%	I	7.5
WI	05367154	Sucker Creek at Loch Lomond Blvd near Birchwood	Boulder/Cobble	No		0-10%	Fluvial	None	0-10%	0-10%	76-100%	76-100%	0-10%	0-10%	I	7
WI	05367190	Hemlock Creek at County Trunk Hghwy F near Mikana	Boulder/Cobble	No	26-50%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	0-10%	0-10%	I	8
WI	05393500	Spirit River at Spirit Falls	Boulder/Cobble	No	76-100%	11-25%	None	None	0-10%	0-10%	76-100%	26-50%	0-10%	0-10%	I	8

Appendix C-v – Rapid Geomorphic Assessments carried out at USGS gages with sufficient suspended-sediment data in the Northern Central Hardwood Forests, Ecoregion 51.

State	Gage number	Gage identification	Bed material	Bed or bank protection	Incision	Constriction	Streambank erosion		Streambank instability		Woody vegetative cover		Bank accretion		Stage of channel evolution	Channel stability index
							Left	Right	Left	Right	Left	Right	Left	Right		
WI	04071000	Oconto River near Gillett	Boulder/Cobble	No	76-100%	0-10%	None	None	0-10%	0-10%	51-75%	26-50%	51-75%	51-75%	VI	6
WI	04071795	Pensaukee River near Krakow	Gravel	No	76-100%	0-10%	None	Fluvial	0-10%	0-10%	26-50%	51-75%	0-10%	0-10%	I	9.5
WI	04071858	Pensaukee River near Pensaukee	Boulder/Cobble	No	26-50%	0-10%	Fluvial	Fluvial	0-10%	0-10%	51-75%	26-50%	0-10%	0-10%	III	13.5
WI	04072233	Lancaster Brook at Shawano Ave at Horward	Sand	Yes	51-75%	0-10%	None	None	0-10%	0-10%	11-25%	51-75%	0-10%	0-10%	I	10
WI	04075365	Evergreen River below Evergreen Falls near Langlade	Gravel	No	76-100%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	76-100%	76-100%	I	3
WI	04077630	Red River at Morgan Road near Morgan	Boulder/Cobble	No	76-100%	26-50%	None	None	0-10%	0-10%	76-100%	76-100%	0-10%	0-10%	I	8
WI	04078500	Embarrass River near Embarrass	Gravel	No	51-75%	0-10%	Mass Wasting	Fluvial	51-75%	11-25%	76-100%	76-100%	26-50%	11-25%	V	14.5
WI	04080798	Tomorrow River near Nelsonville	Boulder/Cobble	No	76-100%	26-50%	Fluvial	None	0-10%	0-10%	76-100%	76-100%	0-10%	0-10%	I	9
WI	04085200	Kewaunee River near Kewaunee	Boulder/Cobble	No	76-100%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	11-25%	0-10%	I	5.5
MI	04126520	Manistee River at Manistee	Sand	2 Banks	26-50%	76-100%	None	None	11-25%	0-10%	0-10%	0-10%	0-10%	0-10%	II	22.5
MI	04127250	Boardman River at Cass Road near Traverse City	-	-	-	-	-	-	-	-	-	-	-	-	II	-
MI	04127490	Boardman River at Traverse City	-	-	-	-	-	-	-	-	-	-	-	-	II	-
MI	04127498	Hospital Creek at Traverse City	Gravel	No	76-100%	0-10%	None	Fluvial	0-10%	0-10%	11-25%	11-25%	0-10%	0-10%	I	11
MI	04127520	Mitchell Creek at Traverse City	Sand	No	76-100%	0-10%	None	None	0-10%	0-10%	26-50%	26-50%	76-100%	76-100%	I	6
MI	04127528	Acme Creek at HWY 31 at Acme	Sand	No	76-100%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	76-100%	76-100%	I	4
MI	04127535	Yuba Creek near Acme	-	-	-	-	-	-	-	-	-	-	-	-	II	-
MI	04127550	Tobeco Creek near Elk Rapids	Gravel	Yes	76-100%	51-75%	Fluvial	Fluvial	26-50%	26-50%	11-25%	11-25%	51-75%	51-75%	V	16
MI	04127600	Battle Creek near Williamsburg	Sand	No	76-100%	0-10%	None	None	0-10%	0-10%	51-75%	26-50%	51-75%	26-50%	I	7
MN	05030150	Otter Trail River near Perham														0
MN	05267000	Mississippi River near Royalton	Gravel	No	51-75%	0-10%	None	Fluvial	0-10%	11-25%	76-100%	76-100%	76-100%	76-100%	VI	7
MN	05275000	Elk River near Big Lake	Gravel	No	51-75%	0-10%	Fluvial	Fluvial	0-10%	26-50%	51-75%	51-75%	11-25%	26-50%	VI	12
MN	05276005	North Fork Crow River above Paynesville	Gravel	No	0-10%	0-10%	None	Mass Wasting	0-10%	76-100%	0-10%	0-10%	76-100%	0-10%	V	20
MN	05288500	Mississippi River near Aonoka	Gravel	No	51-75%	0-10%	Fluvial	None	0-10%	0-10%	76-100%	76-100%	76-100%	76-100%	VI	6.5
MN	05288705	Shingle Creek at Queen Avenue in Minneapolis	Sand	No	0-10%	0-10%	Fluvial	Fluvial	0-10%	0-10%	51-75%	51-75%	26-50%	11-25%	VI	15
MN	05330000	Minnesota River near Jordan	Sand	No	26-50%	0-10%	None	Mass Wasting	0-10%	76-100%	76-100%	0-10%	76-100%	11-25%	V	16.5
MN	05330902	Nine Mile Creek near James Circle at Bloomington	Boulder/Cobble	Yes	-	-	-	-	-	-	-	-	-	-	II	2
MN	05331000	Mississippi River at St. Paul	-	2 Banks	-	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	0-10%	0-10%	II	8
MN	05338500	Snake River near Pine City	Boulder/Cobble	No	51-75%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	0-10%	0-10%	VI	8.5
WI	05338955	Wood River at North Williams Road near Grantsburg	Sand	No	26-50%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	26-50%	51-75%	VI	9
WI	05340500	St. Croix River at St. Croix Falls	-	-	-	-	-	-	-	-	-	-	-	-	II	-
WI	05341500	Apple River near Somerset	-	-	-	-	-	-	-	-	-	-	-	-	II	-
WI	05364850	Duncan Creek Tributary near Tilden	Sand/Gravel	No	76-100%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	0-10%	0-10%	I	7.5
WI	05367055	Chippewa River near Caryville	Gravel	No	51-75%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	51-75%	51-75%	VI	6.5
WI	05368000	Hay River at Wheeler	Sand/Gravel	No	11-25%	0-10%	None	Fluvial	0-10%	11-25%	76-100%	76-100%	51-75%	0-10%	VI	12
WI	05381350	Levis Creek at Black River Falls	Sand	1 Bank	26-50%	0-10%	None	Fluvial	0-10%	0-10%	76-100%	76-100%	11-25%	26-50%	VI	12
WI	05397500	Eau Claire River at Kelly	Boulder/Cobble	No	76-100%	0-10%	None	None	0-10%	0-10%	51-75%	26-50%	0-10%	0-10%	I	7.5
WI	05399500	Big Eau Pleine River at Stratford	Gravel	No	76-100%	0-10%	None	Fluvial	0-10%	0-10%	76-100%	76-100%	0-10%	0-10%	I	8
WI	05399550	Fenwood Creek at Bradley	Boulder/Cobble	Yes	76-100%	11-25%	None	None	0-10%	11-25%	0-10%	26-50%	0-10%	0-10%	I	9.5
WI	05399580	Fenwood Creek at Halder	Gravel	No	76-100%	0-10%	Mass Wasting	None	51-75%	0-10%	11-25%	0-10%	11-25%	76-100%	V	14.5
WI	05399600	Big Eau Pleine River near Knowlton	-	-	-	-	-	-	-	-	-	-	-	-	II	-
WI	05400650	Little Plover River at Plover	Sand	2 Banks	76-100%	11-25%	None	None	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	I	16
WI	05401050	Tenmile Creek near Nekoosa	Sand	No	76-100%	0-10%	Mass Wasting	None	51-75%	11-25%	26-50%	76-100%	0-10%	51-75%	V	14.5
WI	05401535	Big Roche A Cri Creek near Adams	Gravel	No	51-75%	11-25%	Mass Wasting	None	51-75%	0-10%	51-75%	0-10%	11-25%	76-100%	V	15.5
WI	05403500	Lemonweir River at New Lisbon	-	-	-	-	-	-	-	-	-	-	-	-	II	-
WI	05403630	Hulbert Creek near Wisconsin Dells	Sand	No	51-75%	0-10%	None	Fluvial	0-10%	0-10%	76-100%	76-100%	0-10%	0-10%	I	10

Appendix D-i – Mean annual and $Q_{1.5}$ suspended-sediment yield data separated by drainage basin size-class and channel stability for the Northwestern Glaciated Plains, Ecoregion 46.

ALL SITES

	Mean annual yield in T/y/km²				Yield at the $Q_{1.5}$ in T/d/km²			
	Drainage Basin area in km² (less than)				Drainage Basin area in km² (less than)			
	100	1000	10000	100000	100	1000	10000	100000
10th Percentile		0.307	0.139	0.085	0.517	0.00637	0.00273	0.000829
25th Percentile		**0.659**	**0.213**	**0.189**	**0.618**	**0.0104**	**0.00359**	**0.00177**
50th Percentile		**3.05**	**0.579**	**0.461**	**0.786**	**0.0959**	**0.0394**	**0.00393**
75th Percentile		**5.95**	**7.84**	**1.32**	**0.9637**	**0.3796**	**0.1719**	**0.00767**
90th Percentile		32.1	8.35	2.72	1.07	1.81	0.232	0.0284
Number	0	6	9	12	3	9	10	15

STABLE SITES

	Mean annual yield in T/y/km²				Yield at the $Q_{1.5}$ in T/d/km²			
	Drainage Basin area in km² (less than)				Drainage Basin area in km² (less than)			
	100	1000	10000	100000	100	1000	10000	100000
10th Percentile		0.255	0.169	0.0728		0.00485	0.00213	0.000455
25th Percentile		**0.567**	**0.186**	**0.0787**		**0.00814**	**0.00269**	**0.00167**
50th Percentile		**0.934**	**0.213**	**0.206**		**0.0265**	**0.00363**	**0.00348**
75th Percentile		**5.17**	**0.396**	**0.35**		**0.209**	**0.00597**	**0.00436**
90th Percentile		5.80	0.506	0.48		0.510	0.00738	0.00581
Number	0	5	3	5	0	6	3	8

UNSTABLE SITES

	Mean annual yield in T/y/km²				Yield at the $Q_{1.5}$ in T/d/km²			
	Drainage Basin area in km² (less than)				Drainage Basin area in km² (less than)			
	100	1000	10000	100000	100	1000	10000	100000
10th Percentile			2.90	0.165			0.0371	0.00140
25th Percentile			**6.68**	**0.204**			**0.074**	**0.00144**
50th Percentile		**58.0**	**7.84**	**1.534**	**0.786**	**3.20**	**0.142**	**0.01733**
75th Percentile			**7.89**	**3.43**			**0.216**	**0.03413**
90th Percentile			9.25	4.49			0.276	0.0358
Number	0	1	5	4	1	2	6	4

Appendix D-ii – Mean annual and $Q_{1.5}$ suspended-sediment yield data separated by drainage basin size-class and channel stability for the Western Corn Belt Plains, Ecoregion 47.

ALL SITES

	Mean annual yield in T/y/km² Drainage Basin area in km² (less than)				Yield at the $Q_{1.5}$ in T/d/km² Drainage Basin area in km² (less than)			
	100	**1000**	**10000**	**100000**	**100**	**1000**	**10000**	**100000**
10th percentile	27.9	8.39	18.9	1.23	55.5	0.144	0.473	0.0667
25th percentile	**55.8**	**25.6**	**46.9**	**6.23**	**64.2**	**0.66**	**1.00**	**0.113**
50th percentile	**123**	**119**	**94.7**	**17.0**	**380**	**9.03**	**3.20**	**0.314**
75th percentile	**267**	**560**	**375**	**62.0**	**471**	**29.9**	**41.6**	**1.95**
90th percentile	361	617	636	115.63	1134	142	95.2	7.18
Number	6	8	19	7	5	10	19	8

STABLE SITES

	Mean annual yield in T/y/km² Drainage Basin area in km² (less than)				Yield at the $Q_{1.5}$ in T/d/km² Drainage Basin area in km² (less than)			
	100	**1000**	**10000**	**100000**	**100**	**1000**	**10000**	**100000**
10th percentile		12.6	18.2			0.115	0.472	
25th percentile		**19.6**	**29.2**			**0.150**	**0.810**	
50th percentile		**31.3**	**56.7**	**9.08**		**1.57**	**1.13**	**0.249**
75th percentile		**40.2**	**87.1**			**4.40**	**2.98**	
90th percentile		45.5	102			12.1	3.33	
Number	0	3	8	2	0	5	8	2

UNSTABLE SITES

	Mean annual yield in T/y/km² Drainage Basin area in km² (less than)				Yield at the $Q_{1.5}$ in T/d/km² Drainage Basin area in km² (less than)			
	100	**1000**	**10000**	**100000**	**100**	**1000**	**10000**	**100000**
10th percentile	54.1	80.4	40.0	12.7	55.5	5.68	0.457	0.156
25th percentile	**112**	**188**	**98.7**	**14.9**	**64.2**	**13.7**	**5.61**	**0.210**
50th percentile	**226**	**551**	**307**	**18.6**	**380**	**34.1**	**41.6**	**0.299**
75th percentile	**335**	**585**	**625**	**62.0**	**471**	**92.9**	**89.1**	**3.44**
90th percentile	383	649	665	88.0	1134	387	100	5.33
Number	4	5	10	3	5	5	10	3

Appendix D-iii – Mean annual and $Q_{1.5}$ suspended-sediment yield data separated by drainage basin size-class and channel stability for the Northern Lakes and Forest, Ecoregion 50.

ALL SITES

	Mean annual yield in T/y/km² Drainage Basin area in km² (less than)				Yield at the $Q_{1.5}$ in T/d/km² Drainage Basin area in km² (less than)			
	100	1000	10000	100000	100	1000	10000	100000
10th percentile		0.882	0.839		0.0756	0.0109	0.0117	
25th percentile		**1.16**	**1.28**		**0.113**	**0.0164**	**0.0247**	
50th percentile		**2.36**	**1.80**		**0.176**	**0.0726**	**0.0398**	
75th percentile		**6.07**	**4.64**		**0.199**	**0.190**	**0.119**	
90th percentile		29.7	34.0		0.213	1.14	3.11	
Number	2	14	13	1	3	14	13	1

STABLE SITES

	Mean annual yield in T/y/km² Drainage Basin area in km² (less than)				Yield at the $Q_{1.5}$ in T/d/km² Drainage Basin area in km² (less than)			
	100	1000	10000	100000	100	1000	10000	100000
10th percentile		0.873	1.06			0.00838	0.00940	
25th percentile		**0.877**	**1.29**			**0.0109**	**0.0201**	
50th percentile		**1.16**	**1.52**			**0.0155**	**0.0282**	
75th percentile		**1.43**	**1.85**			**0.0216**	**0.0369**	
90th percentile		2.81	3.23			0.110	0.0636	
Number	1	9	8	1	1	9	8	1

UNSTABLE SITES

	Mean annual yield in T/y/km² Drainage Basin area in km² (less than)				Yield at the $Q_{1.5}$ in T/d/km² Drainage Basin area in km² (less than)			
	100	1000	10000	100000	100	1000	10000	100000
10th percentile								
25th percentile								
50th percentile								
75th percentile								
90th percentile								
Number	0	2	1	0	0	2	1	0

Appendix D-iv – Mean annual and $Q_{1.5}$ suspended-sediment yield data separated by drainage basin size-class and channel stability for the Northern Central Hardwood Forest, Ecoregion 51.

ALL SITES

	Mean annual yield in T/y/km^2 Drainage Basin area in km^2 (less than)				Yield at the $Q_{1.5}$ in T/d/km^2 Drainage Basin area in km^2 (less than)			
	100	1000	10000	100000	100	1000	10000	100000
10th percentile	1.01	2.26	0.929	1.73	0.0268	0.0537	0.0157	0.0217
25th percentile	**1.33**	**2.94**	**1.25**	**2.01**	**0.0534**	**0.0654**	**0.0231**	**0.0370**
50th percentile	**1.87**	**4.63**	**1.85**	**3.13**	**0.0979**	**0.1424**	**0.0308**	**0.0415**
75th percentile	**4.14**	**4.97**	**2.99**	**8.87**	**0.133**	**0.298**	**0.0448**	**0.0715**
90th percentile	5.50	6.87	9.01	15.6	0.155	0.777	0.602	0.138
Number	3	11	6	5	3	11	6	5

STABLE SITES

	Mean annual yield in T/y/km^2 Drainage Basin area in km^2 (less than)				Yield at the $Q_{1.5}$ in T/d/km^2 Drainage Basin area in km^2 (less than)			
	100	1000	10000	100000	100	1000	10000	100000
10th percentile		2.31	1.28			0.0456	0.0249	
25th percentile		**2.40**	**1.53**			**0.0545**	**0.0303**	
50th percentile		**3.54**	**2.49**			**0.101**	**0.0410**	
75th percentile		**5.69**	**6.16**			**0.414**	**0.325**	
90th percentile		7.59	11.3			0.90	0.823	
Number	2	4	4	2	2	4	4	2

UNSTABLE SITES

	Mean annual yield in T/y/km^2 Drainage Basin area in km^2 (less than)				Yield at the $Q_{1.5}$ in T/d/km^2 Drainage Basin area in km^2 (less than)			
	100	1000	10000	100000	100	1000	10000	100000
10th percentile		3.81				0.0840		
25th percentile		**4.34**				**0.1028**		
50th percentile		**4.68**				**0.162**		
75th percentile		**4.85**				**0.266**		
90th percentile		5.07				0.573		
Number	1	4	0	1	1	5	0	1